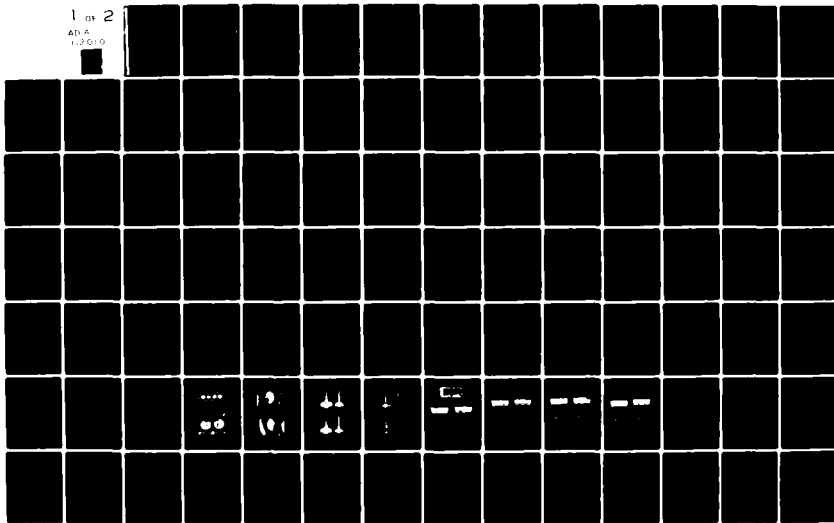
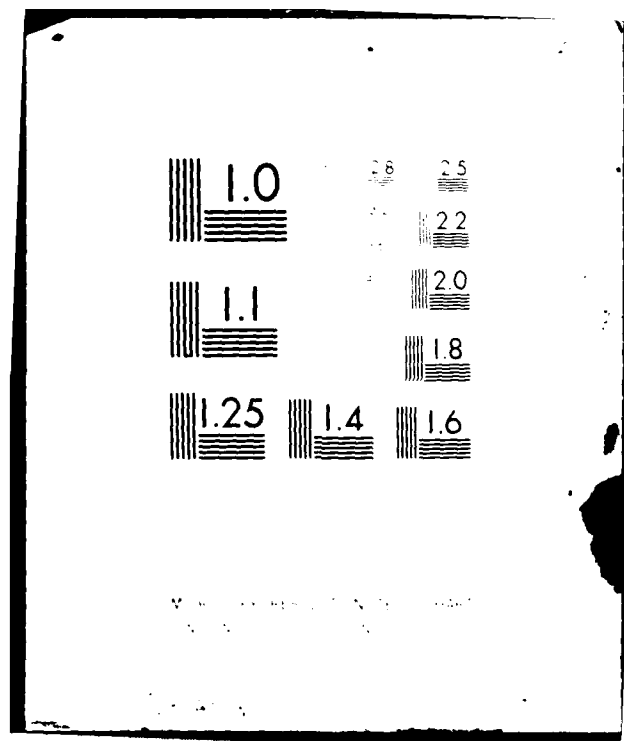


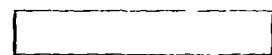
AD-A112 010 SOUTHWEST RESEARCH INST SAN ANTONIO TX ARMY FUELS AN--ETC F/6 21/4
IMPACT OF GASOHOL ON THE L-141 AND LDT-465-1C ENGINES.(U)
UNCLASSIFIED DEC 81 W E LIKOS, D M YOST DAAK70-80-C-0001
AFLRL-148 NL

1 of 2
AD-A
1-2010





12



IMPACT OF GASOHOL ON THE L-141 AND LDT-465-1C ENGINES

**INTERIM REPORT
AFLRL No. 148**

AD A112010

By

W.E. Likos

D.M. Yost

**U.S. Army Fuels and Lubricants Research Laboratory
Southwest Research Institute
San Antonio, Texas**

Under Contract to

**U.S. Army Mobility Equipment Research
and Development Command
Energy and Water Resources Laboratory
Fort Belvoir, Virginia**

Contract No. DAAK70-82-C-0001

Approved for public release; distribution unlimited

December 1981

DTIC FILE COPY



Disclaimers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Trade names cited in this report do not constitute an official endorsement or approval of the use of such commercial hardware or software.

DDC Availability Notice

Qualified requestors may obtain copies of this report from Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314.

Disposition Instructions

Destroy this report when no longer needed. Do not return it to the originator.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

DTIC
MAR 13 1982
H

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Abstract (continued)

Simulated driveability tests with the L-141 engine on a dynamometer showed differences in engine response between the different fuels, but actual vehicle tests proved that driveability was not altered. A relatively short endurance test with the L-141 engine on gasohol fuel indicates, based on engine oil analysis, no significant change in engine wear rates. The endurance test did indicate, however, that more frequent oil drain intervals may be required due to TBN depletion of the engine oil. Cold start testing of the LDT-465-1C engine indicates that gasohol is of inadequate cetane number to sustain normal engine operation. Thus, it is recommended that gasohol not be used in the LDT-465 family of engines.

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	<input type="checkbox"/>
By _____	
Distribution/	
Availability	
Dist _____	

A



Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FOREWORD

This work was conducted at the U.S. Army Fuels and Lubricants Research Laboratory (USAFLRL) located at Southwest Research Institute, San Antonio, TX under contracts DAAK70-80-C-0001 and DAAK70-82-C-0001 during the period October 1980 through September 1981. The work was funded by the U.S. Army Mobility Equipment Research and Development Command (MERADCOM), Ft. Belvoir, VA, with Mr. F.W. Schaekel (DRDME-GL) serving as contract monitor. Project technical monitor was Dr. M. Kolobielski (MERADCOM).

ACKNOWLEDGMENTS

The authors hereby acknowledge the assistance provided by the U.S. Army Fuels and Lubricants Research Laboratory (AFLRL) technical and laboratory staff in the performance of the work and preparation of this report. With appreciation for the concepts and guidance offered, recognition is made of Mr. S.J. Lestz, Director, USAFLRL; and Mr. E.C. Owens, Manager, Lubricants & Mechanical Systems, USAFLRL. Special recognition is made of Mr. K.E. Hinton and Mr. L.D. Sievers, chemical/analytical laboratory and engine laboratory supervisors, respectively; Ms. S. Hayes, typist; and Mr. J.W. Pryor and Ms. E.J. Robinett, technical editors.

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
I. INTRODUCTION	5
II. EXPERIMENTAL EQUIPMENT	
A. Steady-State Gasohol Evaluation	6
B. Simulated Driveability	7
C. Endurance Testing	8
D. Fuels and Lubricants	8
E. LDT-465 Evaluation	9
III. TEST PROCEDURES	
A. Gasohol Steady-State Evaluations in L-141 MUTT Engine	14
B. Simulated Driveability	14
C. Endurance Testing	15
D. LDT-465-1C "Cold" Start Procedures	16
IV. DISCUSSION OF RESULTS	
A. Steady-State Evaluation of Gasohol	18
B. Simulated Driveability Results	29
C. Endurance Testing	36
D. Gasohol Evaluation in LDT-465-1C	40
V. CONCLUSIONS	42
VI. RECOMMENDATIONS	43
VII. REFERENCES	44
APPENDICES	
A. Carburetor Specifications	45
B. Simulated Driveability Apparatus	51
C. Equipment List	59
D. Simulated Driveability Data	63
E. Dynamometer Test Cycle	67
F. 150-hour Endurance Test Results	71
G. 150-hour Endurance Test Baseline Results	97

LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Page</u>
1. Fuel System of the LDT-465-1C Before and After Modifications	13
2. Overall Averages of Thermal Efficiencies for Wide-Open Throttle, 178 mm Hg Manifold Vacuum and 358 mm Hg Manifold Vacuum Over the RPM range	18
3. Thermal Efficiency Averages at Wide-Open Throttle	20
4. Thermal Efficiency Averages at 178 mm Hg Manifold Vacuum	20
5. Thermal Efficiency Averages at 358 mm Hg Manifold Vacuum	21
6. Percent Change in Wide-Open Throttle Power Averaged Over all Test Speeds	21
7. BSFC Versus RPM at Wide-Open Throttle	23
8. BSFC Versus RPM at 178 mm Hg Manifold Vacuum	24
9. BSFC Versus RPM at 358 mm Hg Manifold Vacuum	25
10. Overall Average of Volumetric Fuel Consumption	27
11. Wide-Open Throttle Averages of Volumetric Fuel Consumption over the RPM Range	27
12. Volumetric Fuel Consumption at 178 mm Hg Manifold Vacuum Averaged Over the RPM Range	28
13. Volumetric Fuel Consumption at 358 mm Hg Manifold Vacuum Averaged Over the RPM Range	28
14. Examples of Delay, Hesitation and the Area Under the Manifold Pressure Curves	30
15. Hesitation Observed During Vehicle Tests	31
16. Area Measured Under Manifold Pressure Curves	31
17. Delay From Throttle Opening to Stabilized Acceleration Observed During Vehicle Tests	32
18. Example of Lag, Hesitation, and Delay of the RPM Observed During the Dynamometer Tests	33
19. Delay From Throttle Opening to RPM Response Observed During Dynamometer Tests	34
20. Lag From Throttle Opening to the Recovery of of RPM Observed During Dynamometer Tests	35
21. Change in TAN for Gasohol and Unleaded Gasoline Dynamometer Evaluation	38
22. Change in TBN for Gasohol and Unleaded Gasoline Dynamometer Evaluation	38
23. Engine Oil Viscosity at 100°C, cSt Dynamometer Evaluation	39

LIST OF TABLES

1. Characteristics of Test Fuels Versus PD ME-102a and VV-C-1690	10
2. Test Lubricant, MIL-L-2104C/MIL-L-46152B	12
3. Steady State L-141 Gasohol Evaluation Test Matrix	14
4. Cetane No., (R+M)/2, and % Aromatics of Base Gasoline and Gasohol	17
5. Average Operating Conditions for Dynamometer Evaluation With Gasohol	37
6. Summarization of LDT-465-1C Cold Starts with Gasohol	40

I. INTRODUCTION

At this time, about 35 percent of the petroleum consumed in America is imported, with the majority of this oil being supplied by the OPEC countries of the Middle East. The importing of this oil places a heavy burden on the U. S. economy. Furthermore, as was demonstrated during the 1973 oil embargo, the country's fuel supply is vulnerable to the political flux of the Middle East countries.

Agencies of the federal government responded to the oil embargo by initiating research for fuels derived from resources other than petroleum. Ethanol has been among those fuels being examined. Although 30 percent of the bulk industrial grade ethanol is produced from a petroleum derivative at the present time, alternate sources are available.

Ethanol can be produced from several commercial crops, such as wheat, corn, sugarcane, and sorghum. The United States is capable of growing these crops well in excess of the domestic and export food market requirements. For example, in 1978, if the 18.3 million acres of fallow farmland had been cultivated with corn, 3 billion gallons of ethanol fuel could have been produced. Realizing this vast potential for making the country self-sufficient in energy, Congress enacted legislation encouraging the production and use of fermentation-derived ethanol as a motor fuel. Recognizing that with current fermentation technology, ethanol cannot compete with petroleum-derived fuel in the market place, economic incentives were included in the legislative actions. These incentives were enacted with the hope that future developments in microbiology, distillery design, and solar energy would eventually reverse the economics of ethanol production. Because the use of neat alcohol in an automotive engine requires some modifications to the engine, the incentives were aimed at promoting the use of a blend of ethanol in gasoline, which would require no engine modifications.

The legislators decided that a blend of 10 percent (vol, minimum) of ethanol in gasoline would qualify for a 4¢ per gallon excise tax exemption. Furthermore, Public Law 96-107, Section 815, has directed the Department of

Defense to purchase this blend, which has been called gasohol, to the maximum extent possible. Some exceptions were permitted for national security reasons.

It is this mandate, PL 96-107, that promoted this study. This work addresses the impact that the use of gasohol will have on the M-151 Military Utility Tactical Truck (MUTT). Engine dynamometer evaluations were performed to determine the effects of gasohol on fuel consumption, operating efficiencies, engine wear, and driveability.

The feasibility of operating the LDT-465 family of multifuel engines on gasohol was considered of prime importance in evaluating the impact of gasohol on Army tactical vehicles. It was determined, due to the typically low cetane number of a spark ignition (SI) engine fuel, that the startability of this family of engines on the gasohol fuel would be the critical factor in determining its operability.

II. EXPERIMENTAL EQUIPMENT

A. Steady-State Gasohol Evaluation

An L-141 engine, used in the M-151 Military Utility Tactical Truck, was installed on a 130-kW (175-hp) eddy current dynamometer. A controller for the dynamometer provided load and speed control. Engine rpm was measured using a 60-tooth gear, magnetic pick-up, and digital frequency counter. Engine torque was measured by cradling the dynamometer and sensing the torque reaction through a strain gauge-type load cell. The fuel consumption was measured by a Flotron mass flowmeter to 0.05 kg/hr (0.1 lb/hr). A mercury manometer was used to record manifold vacuum.

The current manufacturer of carburetors for the L-141 engine has supplied three different models through the years. Two of these models were identical in performance, differing only in the fuel inlet area. Model No. 12848 was equipped with a return line to the tank. Both models (Nos. 12848 and 13841) are now obsolete. These carburetors were replaced in May 1975 by the

Zenith Model No. 73660 carburetor. This new carburetor is calibrated for a leaner air/fuel ratio than its predecessors in an effort to reduce exhaust emissions. The design is the same for both the low-emission and regular carburetor, differing only in jet sizes. A tabulation of jet sizes is given in Appendix A.

B. Simulated Driveability

The effects of the gasohol fuel on the driveability of the vehicle were simulated on the engine dynamometer. A dynamometer controller was constructed and calibrated to vary the load on the engine in response to the rpm. The controller simulated both the steady-state and inertial components of the road horsepower requirements of the vehicle. The steady-state road horsepower of the M151 vehicle was determined by actual road testing. The inertial component was calculated based upon the gross weight of the M151 vehicle. The controller was provided with circuitry to simulate each of the four forward gear ratios. Accelerations from idle through the four gears to the top speed of 104 km/hr (65 mph) were possible, but could not represent typical driving technique because a clutch was not involved. Since the dynamometer did not have motoring capabilities, coasting down could not be simulated. The details of the electronic circuits and their calibrations are outlined in Appendix B.

The driver plays an important role in vehicle driveability studies. The results of such studies depend on the driver's ability to observe and record the severity of different engine malfunctions. The driver must quantify malfunctions such as hesitation, stumble, surge, stall, and backfire. These observations are generally recorded as the vehicle is operated over a prescribed course. With a trained driver, the results can be consistent, but the outcome can differ according to drivers.

Malfunctions such as hesitation, surge, and stumble are sensed by the driver's perception of motion. Accelerations and rate of change of accelerations (jerk) cannot be observed by the engine dynamometer operator and rated for severity as the vehicle driver would. To overcome this problem, a

technique developed by the Coordinating Research Council (CRC) was adapted to the engine dynamometer experiment.(1)*

In the CRC work, several vehicles were equipped with instrumentation to record manifold vacuum, throttle and choke position, engine rpm, and car speed. These were continuously recorded on a chart recorder as the vehicles were driven a prescribed course. Drivers assigned demerits in the usual manner. Irregularities in engine speed and manifold vacuum were correlated with malfunction severity as rated subjectively by the drivers. The correlations obtained were considered appropriate for the test vehicles (a total of eight different makes and models), but the extent to which they apply to other vehicles was not determined.

In the simulated driveability studies at U.S. Army Fuel and Lubricants Laboratory (AFLRL), the engine was instrumented to record fuel flow rate, throttle position, engine rpm, manifold vacuum, torque and the time derivative of rpm. These data were simultaneously recorded on a six-pen chart recorder as in the CRC work.

The vehicle was also instrumented in much the same manner. The six-pen recorder was used to record rpm, manifold vacuum, and throttle position. A tabulation of the equipment is in Appendix C.

C. Endurance Testing

For the 150-hour endurance test phase of the gasohol evaluation in the L-141 engine, no modifications were made to the existing engine dynamometer installation.

D. Fuels and Lubricant

The base fuels used for all phases of testing in the L-141 engine were readily available locally. The fuels consisted of an unleaded regular gasoline, a leaded regular gasoline, and a commercially available unleaded gasohol.

* Underscored numbers in parentheses refer to the list of references at the end of this report.

Three other fuels evaluated were blends of one or two of the base fuels and anhydrous ethanol. All ethanol used for blending was SDA-28A ethanol, and all gasohol blends were adjusted to match the ethanol content of commercial gasohol. For the dynamometer testing of the M141 engine, the following fuels were used: commercial GASOHOL, unleaded regular, a blend of SDA28 ethanol and leaded regular, and a blend of 45%/45%/10% unleaded regular/leaded regular/SDA-28A. Simulated driveability work was performed using GASOHOL and leaded regular. The physical inspection properties of all test fuels, and comparisons to VV-G-1690B (2) or purchase description ME-102a (3), are given in Table 1.

The lubricant used for all phases of fuel testing was a qualified MIL-L-2104C/MIL-L-46152B (4,5) grade 30 lubricant. This engine oil, REO-203, was obtained from a repository located on the grounds of Southwest Research Institute. The inspection properties for this lubricant are shown in Table 2.

E. LDT-465 Evaluation

The engine representative of the LD-465 family of multifuel engines available for testing at AFLRL was in the LDT-465-1C configuration. For the evaluations, the fuel system of the LDT-465-1C was reduced to a minimal configuration in order to minimize the fuel required for each trial. This modified configuration included eliminating the fuel filters, heat exchangers, and flowmeter, which allowed the engine to be run from a 2-gallon tank. Figure 1 shows the fuel system before and after the modifications. The engine itself was coupled to a 224-kW (300-hp) universal eddy current dynamometer with absorbing and motoring capabilities. A controller for the dynamometer provided load and speed control. Engine speed was monitored with a 60-tooth gear, magnetic pickup, and digital frequency counter. The torque was measured with a hydraulic load cell attached to a torque arm of the cradled dynamometer, and read with a dial-gauge calibrated from psi to lb-ft.

TABLE 1. CHARACTERISTICS OF TEST FUELS VS PD ME-102a AND VV-G-1690

Property	Unleaded Gasohol	Leaded Gasohol	Unleaded/Leaded 50/50 Gasohol	PD ME-102a Purchase Description
Fuel Code	AL-10151G	---	AL-10633-G	---
Gravity, °API	58.0	60.2	52.8	---
Reid Vapor Pressure (1) kPa (psf)	84.1 (12.2)	73.8 (10.7)	51.7 (7.5)	62.1 103.4 (9 15)
Distillation, °C (°F)				
IBP	30 (87)	29 (85)	35 (96)	---
10% evap	47 (117)	48 (119)	55 (132)	---
20% evap	55 (131)	56 (133)	61 (142)	---
50% evap	95 (203)	78 (172)	105 (222)	121 110 (250 230)
90% evap	169 (337)	162 (324)	162 (323)	190 185 (374 365)
EP	205 (401)	215 (420)	210 (410)	225 (437)
Recovered, %	98.5	98	99.0	---
Residue, %	1.5	1.5	1.0	---
Loss, %	0.0	0.5	0.0	---
Existent Gum, mg/100 ml				
Unwashed	4.2	7.2	4.2	Report
Washed	2.8	0.4	1.7	5 max
Oxidation Stability, min.	1440	1440	1440	240 min
Sulfur, wt%	0.01	0.01	0.01	0.10 max
Lead, g/gal.	---	---	---	0.05 max
Phosphorus, mg/gal.	---	---	---	5 max (2)
Aromatic, % (FIA)	31.7	21.3	40.2	24 min
Olefins, % (FIA)	3.0	0.8	4.0	---
Saturates, % (FIA)	65.3	77.8	55.8	---
Research Octane No.	95.7	95.6	97.9	---
Motor Octane No.	85.1	87.2	85.6	---
Higher Heat of Combustion, MJ/kg (Btu/lb)	45.083 (19,382)	41.315 (17,762)	40.557 (17,436)	---
RON + MON/2	90.4	91.4	91.8	---

(1) RVP values are not limiting. The limiting criteria for vapor lock is the temperature at which V/L = 20.

(2) Limiting to base gasoline only.

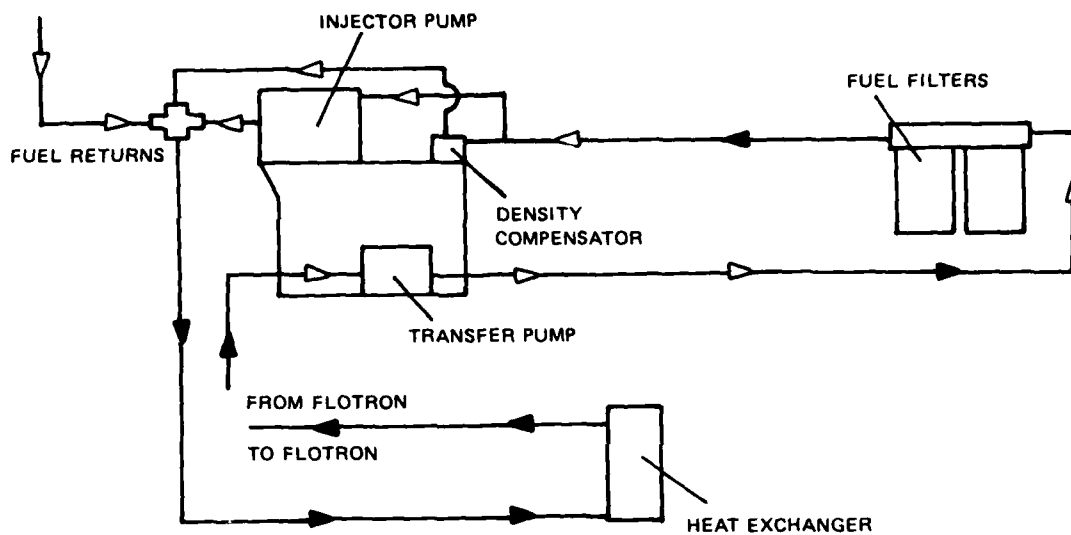
TABLE 1. CHARACTERISTICS OF TEST FUELS VS PD ME-102a and VV-G-1690
Continued

Property	Unleaded Gasoline	Leaded Gasoline	Unleaded/Leaded 50/50 Gasoline	VV-G-001690 Specification
Fuel Code	AL-10152G	AL-10450G	---	---
Gravity, °API	56.1	62.0	54.4	---
Reid Vapor Pressure (1) kPa (psi)	75.2 (10.9)	74.5 (10.8)	54.5 (7.9)	79.3 (11.5 max)
Distillation, °C (°F)				
IBP	30 (87)	25 (78)	32 (90)	---
10% evap	53 (127)	47 (116)	58 (136)	60 (140 max)
20% evap	67 (153)	58 (137)	71 (160)	---
50% evap	104 (219)	95 (203)	110 (230)	116 (240) max
90% evap	159 (319)	164 (328)	167 (332)	185 (65) max
EP	201 (395)	220 (428)	218 (424)	225 (437) max
Recovered, %	98.5	98.0	98.5	---
Residue, %	1.5	1.5	1.5	---
Loss, %	0.0	0.5	0.0	---
Existent Gum, mg/100 ml				
Unwashed	1.4	6.8	4.5	10.0 max
Washed	0.5	0.6	1.5	4.0 max
Oxidation Stability, min.	1440	1440	1440	240 min
Sulfur, wt%	0.01	0.01	0.01	0.10 max
Lead, g/gal.	---	---	---	0.05 max
Phosphorus, mg/gal.	---	---	---	5 max
Aromatic, % (FIA)	37.0	20.4	36.1	45.0 max
Olefins, % (FIA)	3.2	1.1	5.8	Report
Saturates, % (FIA)	59.8	78.5	58.1	---
Research Octane No.	92.2	93.7	95.0	
Motor Octane No.	83.0	86.6	84.7	
Higher Heat of Combustion, MJ/kg (Btu/lb)	46.069 (19,806)	43.334 (18,630)	42.531 (18,285)	
RON + MON/2	87.6	90.2	89.9	

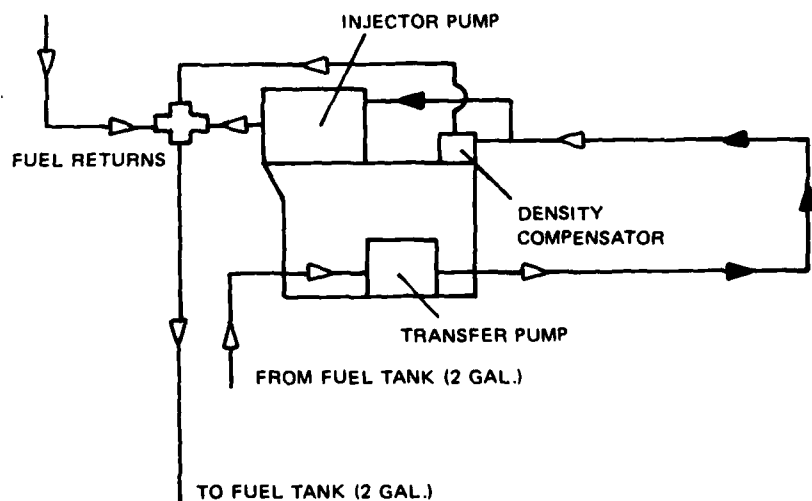
(1) RVP values are not limiting. The limiting criteria for vapor lock is the temperature at which V/L = 20.

TABLE 2. TEST LUBRICANT, MIL-L-2104C/MIL-L-46152B

<u>Property</u>	<u>ASTM Method</u>	<u>RED-203</u>	<u>Specification Requirements MIL-L-2104C/ MIL-L-46152B</u>
Viscosity, cSt			
at 100°C	D 445	11.8	9.3 - 12.5
at 40°C	D 445	104.6	Report
Viscosity Index	D 2270	101	75 min
Flash Point, °C	D 92	241	220 min
Pour Point, °C	D 97	-21	-18 max
Gravity, °API	D 287	27.4	Report
Carbon Residue, %	D 524	1.19	Report
Sulfated Ash, %	D 874	0.93	Report
Total Acid Number	D 664	3.3	Report
Total Base Number	D 664	4.5	Report
Total Base Number	D 664	5.4	Report
Additive Content			
<u>Elemental wt%</u>	<u>Method</u>		
Zinc	AA	0.09	Report
Calcium	AA	0.24	Report
Barium	AA	NIL	Report
Phosphorus	XRF	0.09	Report



a. Test Stand Fuel System for LDT-465-1C



b. LDT-465-1C Fuel System Modified for "Cold" Start Procedures

FIGURE 1. FUEL SYSTEM OF THE LDT-465-1C BEFORE AND AFTER MODIFICATIONS

III. TEST PROCEDURES

A. Gasohol Steady-State Evaluations in L-141 MUTT Engine

The dynamometer test matrix utilized in this phase of the study is outlined in Table 3. Engine rpm and manifold vacuum were the independent variables, while fuel flow and dynamometer load were the dependent variables. Spark timing and coolant temperatures were monitored to ensure proper engine operation during the test runs. The test cycle was run on unleaded gasohol, unleaded gasoline, 50/50 mixture of unleaded and leaded gasoline with 10 vol% anhydrous ethanol, gasohol using leaded regular, and leaded regular for baseline data. Baseline data for the 90-percent blend of 50/50 leaded/unleaded were obtained by arithmetic averaging of the unleaded and leaded fuel results. The above fuels were evaluated using both the obsolete Zenith No. 13841 carburetor and the present Zenith No. 13660 low-emissions carburetor.

TABLE 3. STEADY STATE L-141 GASOHOL EVALUATION TEST MATRIX

<u>Engine Speed, rpm</u>		<u>Manifold Vacuum, mm Hg (inches Hg)</u>	
$\left\{ \begin{array}{c} 1000 \\ 1500 \\ 2000 \\ 2500 \\ 3000 \\ 3500 \\ 4000 \end{array} \right\}$	X	$\left\{ \begin{array}{c} 356 (14) \\ 180 (7) \\ \text{WOT} \end{array} \right\}$	= 21 test conditions

B. Simulated Driveability

The road load simulator was calibrated and installed as described in Appendix B. A pneumatic activator was installed on the throttle, and the chart recorder and associated transducers as outlined in the equipment section were also installed and calibrated.

Acceleration runs were simulated for each gear individually since the lack of a clutch prevented realistic shifting. If the engine was accelerated to a shift point, then switched to the next higher gear, a rapid deceleration of the engine with a subsequent acceleration, somewhat like "speed shifting" would result. Shift points were calculated from the top speed in each gear. To perform a run, the dynamometer excitation was switched off, and a high idle adjustment was set at the initial rpm for the particular gear. Simultaneously, the switch to the excitation circuit would then be closed, and air pressure supplied to the throttle activator. The maximum throttle opening was limited by an adjustment screw. A needle valve placed in the air line regulated the rate at which the throttle opened. Very rapid or slow throttle opening rates were possible. Acceleration runs were made using the unleaded gasoline and unleaded gasohol in the low-emission carburetor. Wide open throttle accelerations were performed with both a very rapid and a gradual opening of the throttle. Accelerations were also made at part-throttle settings by regulating the air pressure supplied to the throttle air cylinder. Settings of the pressure regulator were 8.5, 10.0, and 15.0 psi (WOT), yielding throttle plate openings of approximately 1/3, 1/2, and full.

After making the acceleration runs on the engine dynamometer, the chart recorder was installed in the vehicle. Comparisons of the rpm and manifold vacuum traces to the dynamometer traces provided an indication of how well the simulator duplicated the engine-vehicle performance. Unleaded gasohol and leaded regular gasoline were run in the low-emission carburetor. The leaded regular gasoline was used as the baseline because the unleaded fuel supply had been exhausted during the experimentation to develop the engine dynamometer techniques.

C. Endurance Testing

A dynamometer cycle based on road load measurements from the M-151 vehicles was used to evaluate differences in oil degradation rate with the gasohol fuel. The baseline for comparing oil degradation rates was the data from the L-141 engine run on unleaded gasoline and was presented in Interim Report AFLRL No. 72.(6) The test cycle, Appendix E, simulated an 80-km/hr

(50-mile/hr) road load period, a 56-km/hr (35-mile/hr) high-load period, and an idle period. A 100-hour period of operation with this cycle would thus represent 5430 km (3375 miles) traveled. The lubricant, REO-203, was also used for oil degradation tests in earlier AFLRL studies.(6)

Oil consumption was measured by draining the oil into a weighed container for a fixed length of time (5 min) during the same period in the test cycle. The weight of oil consumed was then determined, and an equal amount of new oil was added. The oil was then returned to the engine. Samples of used oil were taken prior to the fresh oil additions. At the end of the 150-hour endurance test, the engine was disassembled and measured for wear and rated for engine deposits. The engine was rated in accordance with standard CRC diesel engine deposit rating methods. This method was used due to the greater significance it placed on the piston ring area deposits. With this method, varnish is used in depicting coloration, versus lacquer in the spark ignition engine rating codes.

D. LDT-465-1C "Cold" Start Procedures

The cetane numbers of three gasohol blends were experimentally determined in a CFR cetane engine. The gasohol blends made with regular leaded AL-10450-G, unleaded regular AL-10257-G, and AL-8836-G base fuels had cetane numbers of 16, 13, and 12, respectively (Table 4). It was proposed to try a "cold" start of the LDT-465-1C multifuel engine on each of the gasohol blends. The ambient air temperature, cranking speed, time of cranking, time to smooth idle, and full load torque were the quantitative measures used to evaluate engine and fuel performance. The ease of starting and the acceleration to full load were the subjective measures of performance. There were two trials with each fuel to confirm the subjective observations of the engine "operability" and to verify the quantitative results. The "cold" start procedures were initiated with the modified fuel system being purged before each test. The method for purging the fuel system was to start the engine on diesel fuel, switch to the gasohol fuel, and continue running until the fuel system contained only gasohol. The engine was then allowed to "cold soak" overnight, with the trials attempted in the early morning.

TABLE 4. CETANE NO., (R+M)/2, AND % AROMATICS OF
BASE GASOLINE AND GASOHOL

<u>Base Fuel</u>	AL-10450-G Leaded Regular	AL-10257-G Unleaded Regular	AL-8836-G Unleaded Regular
Cetane No. (before ETOH)	19	17	15
R+M/2) (before ETOH)	90.2	NA	90.5
Aromatics, %(before ETOH)	20.4	25.3	46.3
<hr/>			
Cetane No. (Gasohol)	16	13	12
(R+M/2) (Gasohol)	91.4	NA	NA
Aromatics, %(Gasohol)	21.3	NA	NA

IV. DISCUSSION OF RESULTS

A. Steady-State Evaluation of Gasohol

Figure 2 is a bar chart of the percent change in the thermal efficiency averages for the engine conditions test matrix of Table 3. For three of the fuel-carburetor combinations shown, replicate runs were performed. The lines on some bars indicate the highest and lowest replicate values which were then averaged to obtain the bar shown. Thus, the spread of the arrows gives an indication of the experimental variation in the results. The

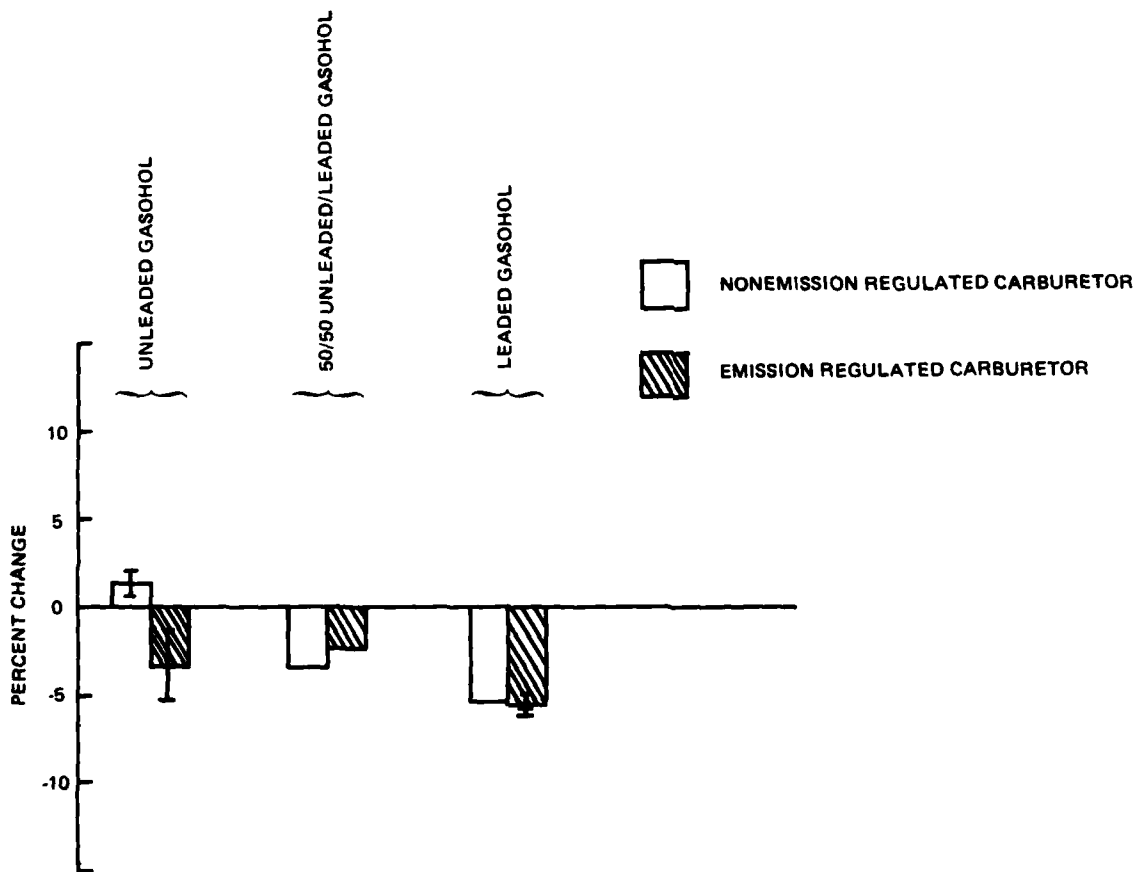


FIGURE 2. OVERALL AVERAGES OF THERMAL EFFICIENCIES FOR WIDE-OPEN THROTTLE, 178 mm MANIFOLD VACUUM AND 358 mm MANIFOLD VACUUM OVER THE RPM RANGE

unleaded fuel in both carburetors was repeated twice. The leaded fuels were repeated twice in the low-emission carburetor and also in a duplicate low-emissions carburetor. The bars shown for this data represent the different carburetors but identical results. These overall averages of the comparisons of gasohol performance to the base fuel indicate a decrease in thermal efficiency of 3 to 5 percent while operating on gasohol, except for unleaded gasohol in the older carburetor. Unleaded gasohol in the obsolete Zenith No. 13841 carburetor resulted in an increase of 1 percent in thermal efficiency.

Figures 3 through 5 are similar to Figure 2 with the exception that each chart now represents only a single load condition. Figure 3 reveals that at wide open throttle, the gasohol fuels yielded a higher thermal efficiency than the base fuels. This increase was on the order of 5 percent. Although the two carburetors produced the same thermal efficiencies using gasohol or base fuel, the maximum power developed by the engine differed with each carburetor. These data are shown in Figure 6. Again, the format of the chart is the same as the previous figures, but the vertical axis has been expanded. As can be seen, the power was not affected when using the older, pre-emissions carburetor. However, the power was down roughly 3 percent when using gasohol in the low-emissions carburetor.

Operation on gasohol at the intermediate load condition of 178 mm Hg of manifold vacuum resulted in lowered thermal efficiencies (Figure 4). For the low-emissions carburetor, the efficiency decreased by 9 to 15 percent. The performance using the older carburetor was not as severely affected. The efficiencies were down by 3 to 6 percent. The unleaded gasohol in the older carburetor was the least affected at this intermediate load point.

At the light load condition of 358 mm Hg of manifold vacuum, thermal efficiency again decreased except for the unleaded fuel used in the pre-emissions regulated carburetor (Figure 5). The older carburetor yielded the poorest thermal efficiency running the 50/50 unleaded/leaded gasohol and the leaded gasohol, averaging from 10 to 15 percent lower than the base fuel. The low-emissions carburetor decreased the thermal efficiencies by 4 to 8 percent. The slight improvement at this load condition for the unleaded

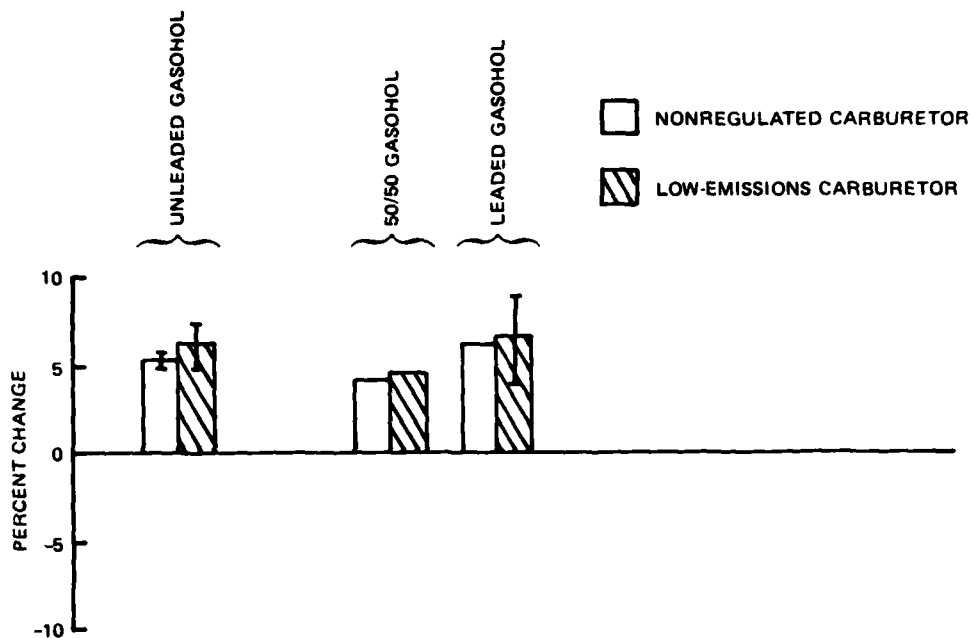


FIGURE 3. THERMAL EFFICIENCY AVERAGES AT WIDE-OPEN THROTTLE

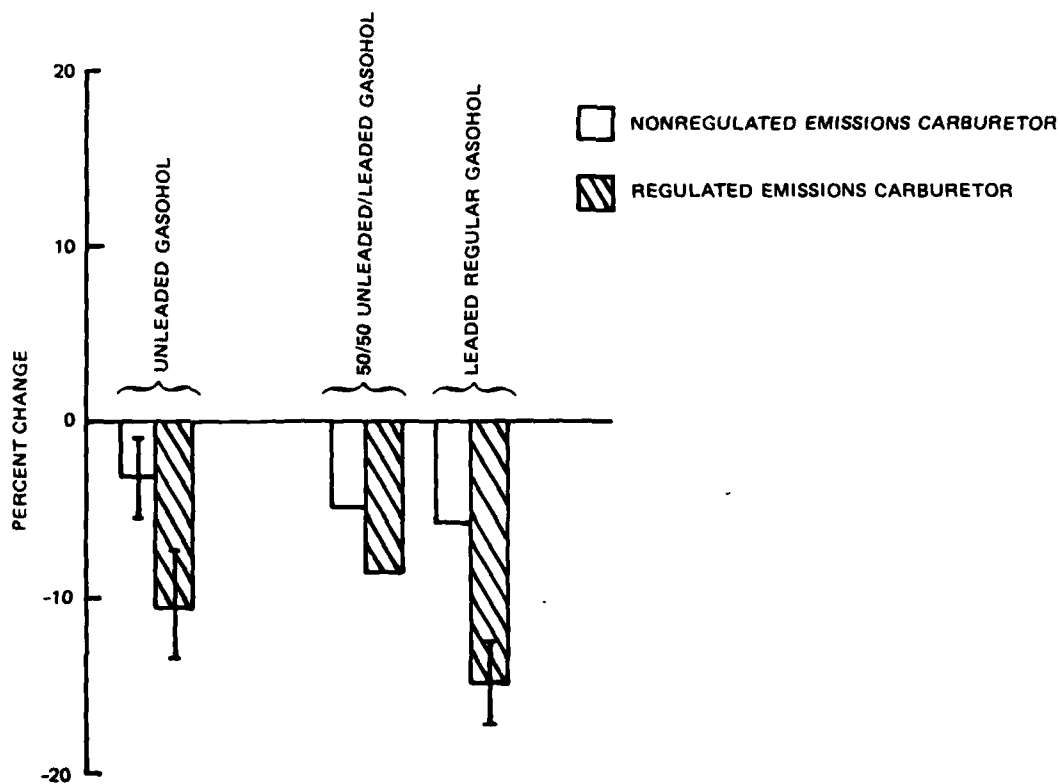


FIGURE 4. THERMAL EFFICIENCY AVERAGES AT 178 mm Hg MANIFOLD VACUUM

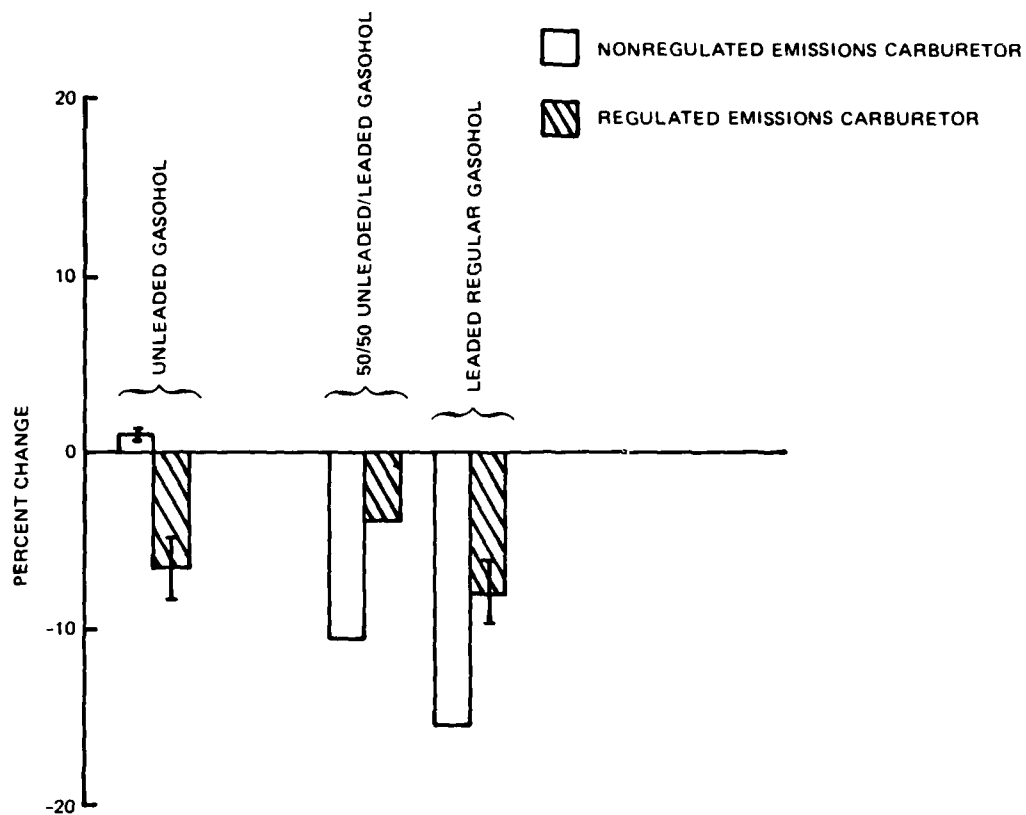


FIGURE 5. THERMAL EFFICIENCY AVERAGES AT 358 mm Hg MANIFOLD VACUUM

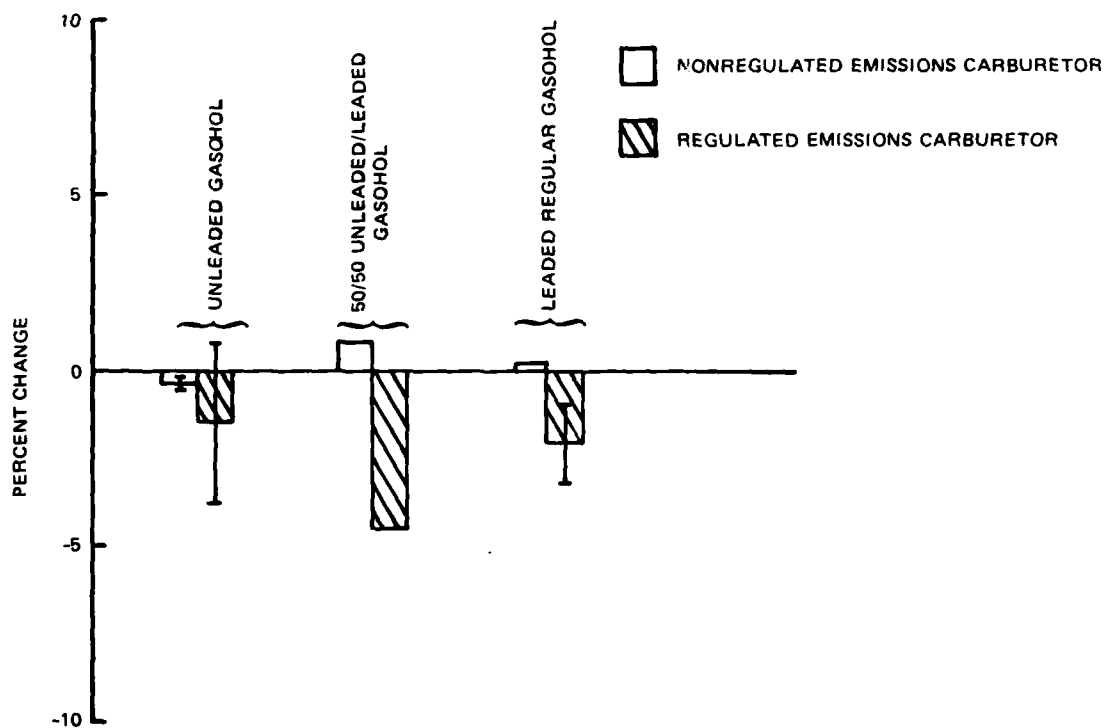


FIGURE 6. PERCENT CHANGE IN WIDE-OPEN THROTTLE POWER AVERAGED OVER ALL TEST SPEEDS

gasohol in the older carburetor resulted in the overall load comparisons also showing an improvement.

Differences in thermal efficiency between base gasoline and gasohol may arise due to two primary reasons: First, the alcohol stoichiometric air-to-fuel ratio is 9 to 1 as compared to an average gasoline ratio of 14.5 to 1. The blending of the alcohol into gasoline lowers the stoichiometric air-to-fuel ratio. Since the carburetion was not altered for gasohol operation, the resultant air-fuel ratio was leaner on gasohol as compared to gasoline operation. Secondly, the ignition timing for a leaner mixture would need to be advanced to compensate for longer ignition delay and slower flame speeds. If it is assumed the spark timing was optimum for the gasoline operation, then the timing would be retarded while operating on gasohol, resulting in lowered torque output and thermal efficiencies.

The air-to-fuel ratio delivered to the engine by the typical carburetor is varied in accordance with the load and rpm. At light load and low speeds, a comparatively rich mixture is required to avoid misfire. This rich mixture is required since some exhaust gases remain in the cylinder at the conclusion of the exhaust stroke. Thus, this exhaust gas becomes a large percentage of the total inlet charge. Thus, the increasing dilution of the inlet air-fuel charge with lowering rpm and rising manifold vacuum decreases the probability of an ignitable charge in the spark gap, requiring the air-fuel ratio to be lowered.

At part-throttle, the mixture is leaned out to the most efficient air-fuel ratio, generally around 16 to 1. This ratio will produce the best economy at cruise. The spark timing is advanced to accommodate the slower flame speeds at the leaner mixture.

At wide-open throttle, a rich mixture is provided to the engine, since maximum torque requires a rich mixture and also prevents the exhaust valve from oxidizing. The spark timing is retarded from the part-throttle cruise setting to avoid knock.

Although air-fuel ratios were not measured, comparison of the low-emission carburetor to the older carburetor's performance provides some understanding of the calibration of the carburetors. This understanding can then be used to explain the gasohol results. Figures 7 through 9 plot the brake specific fuel consumption versus rpm for each load condition. Each plot also shows the fuel flow rate data for each carburetor. The data shown are for one set of runs typical of the average. Since the manifold vacuum is the same for each load condition, a higher fuel flow rate implies a richer mixture at a given rpm.

Starting with the wide open throttle condition (Figure 7), note that the fuel flow is higher (richer) for the low-emission carburetor. The BSFC values are also higher at the low rpm but are the same as the regular carburetor at 4000 rpm. This fact is due to the brake horsepower being higher for the low-emissions carburetor. The horsepower were equal at 1000 rpm,

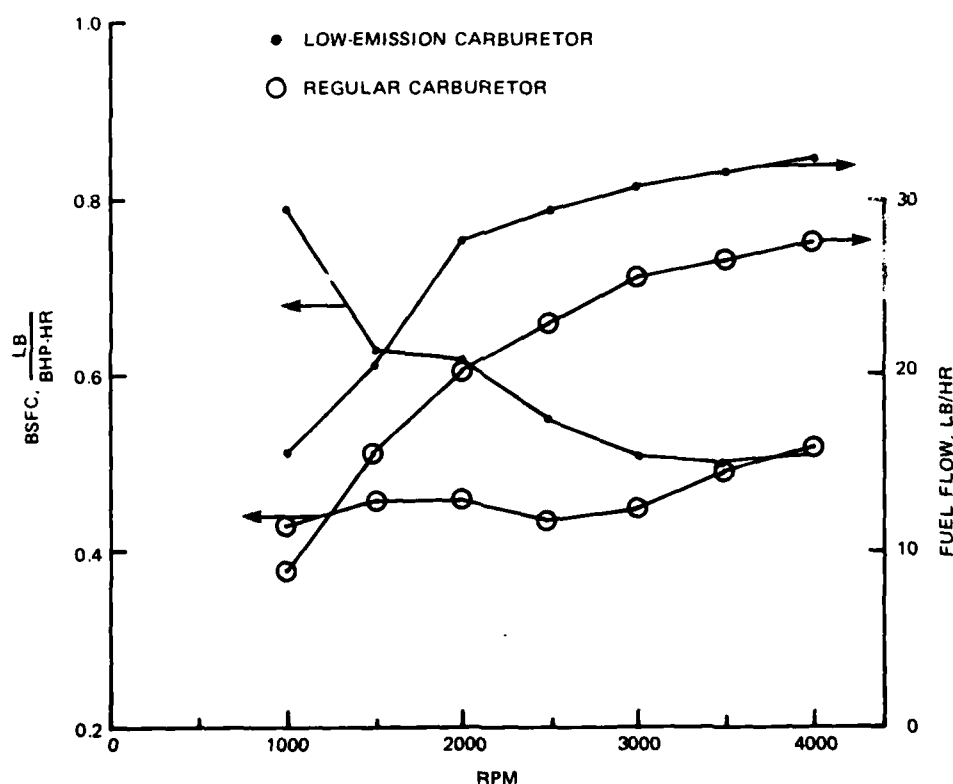


FIGURE 7. BSFC VERSUS RPM AT WIDE-OPEN THROTTLE

but the low-emission carburetor's richer mixture at 4000 rpm produced 64 bhp as compared to the regular carburetor's 54 bhp. This implies then that the low-emission carburetor is too rich at low speeds, but closer to the correct mixture at higher speeds. The regular carburetor is calibrated too lean at high speed to produce the maximum power, but at low speed the lean mixture is correct.

At the 178 mm Hg manifold vacuum condition (Figure 8), the fuel flow rates are nearly identical, but the horsepower developed by the low-emission carburetor was lower. This fact resulted in the higher BSFC values shown. The differences in bhp developed could be due to spark timing or differences in the maldistribution of the air-fuel mixture among the cylinders. The differences in jetting (Appendix A) in the low-emission carburetor would put a higher fuel flow through the power jet circuit with less through the main jet. This could produce differences in the mixture flow patterns in the manifold.

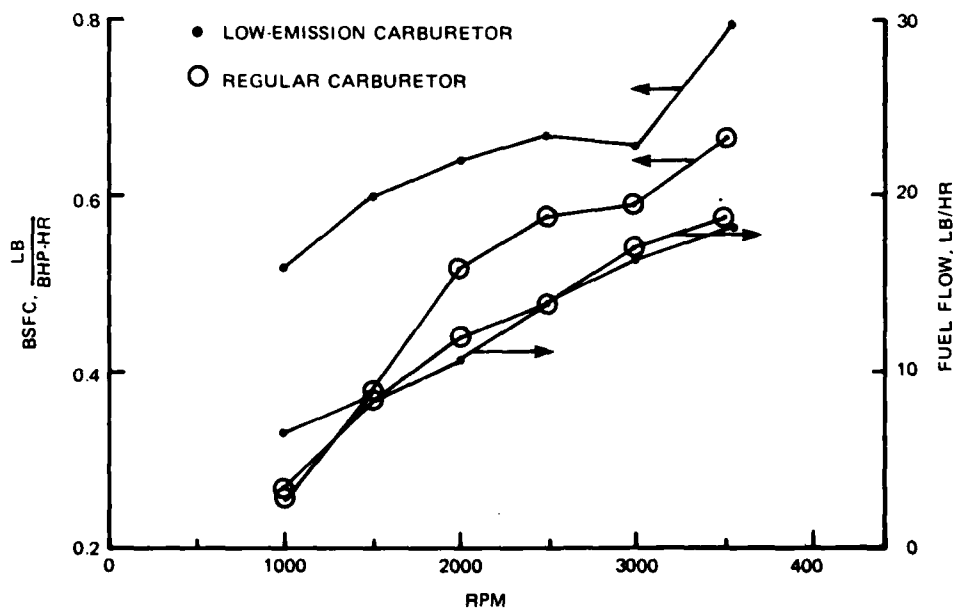


FIGURE 8. BSFC VERSUS RPM AT 178 mm Hg MANIFOLD VACUUM

At light load of 358 mm Hg of manifold vacuum (Figure 9), the low-emission carburetor flow rate was less (leaner) than the regular carburetor. This resulted in lower horsepower output and higher brake specific fuel consumption. The low-emission carburetor was calibrated leaner than that required for the most efficient operation. The regular carburetor ran at a close to the ideal (or at the ideal) mixture for the best thermal efficiency at the light load.

Returning to the thermal efficiency data of Figures 2 through 5, possible explanations of trends will now be offered. At wide-open throttle, the leaning effect of the gasohol resulted in thermal efficiencies increasing for both carburetors. The power developed was less on gasohol because at high speeds the mixture was now leaner than that required for maximum power.

At the intermediate load (Figure 4), the leaning effect of the gasohol aggravated the normal part-load lean operation. The maldistribution of the low-emission carburetor may have been increased by the higher latent heat of

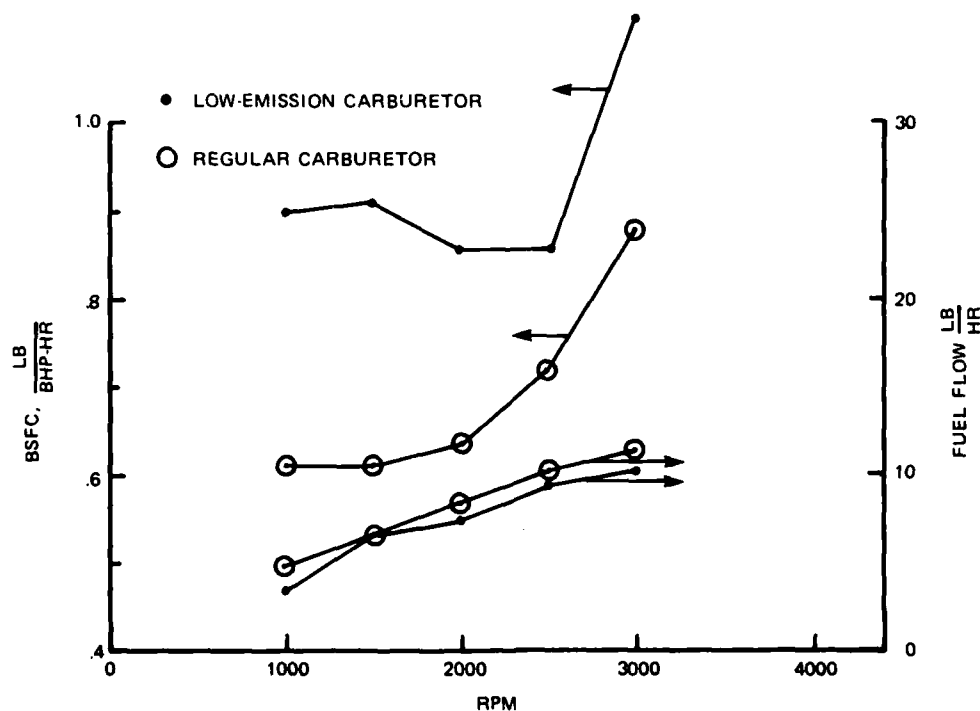


FIGURE 9. BSFC VERSUS RPM AT 358 mm Hg MANIFOLD VACUUM

evaporation of the gasohol, thereby affecting those results more than the older carburetors.

At light load (Figure 5), the older carburetor did poorer than the low-emissions carburetor on gasohol, with the exception of the unleaded gasohol. For the 50/50 leaded/unleaded blend and leaded gasohol, the drop in efficiency is due to the further leaning of the mixture by the alcohols. The regular carburetor had been running at, or close to, the optimum for maximum power on the base fuel so the leaning effect of the gasohol had a severe effect on the results. This is similar to the gasohol effect at wide-open throttle with the low-emission carburetor previously discussed.

A slight improvement in thermal efficiency resulted at 358 mm Hg when using the older carburetor. Higher Reid Vapor Pressure (84.1 kPa) as compared to its base fuel RVP of 75.2 kPa (Table 1) (RVP's of all other gasohols were less) and a high heat of combustion combined with the richer calibration resulted in the improved performance seen with the low-emission carburetor.

Figures 10 through 13 illustrate the increase of volumetric fuel consumption for the different fuel and carburetors tested. The data and format are the same as in Figures 2 to 5. The result represents the increase in the fuel volume flow rate per brake horsepower. The results may also be interpreted as the decrease in mileage of the vehicle in comparison with the base fuel. Note that even where thermal efficiency increases were observed, for example, the older carburetor using unleaded gasohol, the mileage can still decrease as compared to base fuel performance. This decrease is due to the lower heat of combustion of the alcohol fuels. The miles per gallon will show an improvement only after the thermal efficiency increases by 5 percent. The trends in this data are the same as the thermal efficiency results, both being based on the fuel flow and horsepower measurements.

The impact of gasohol on the vehicle mileage can be seen from the volumetric consumption data. If on-post operation of the vehicle is assumed to consist of an equal mix of light load, intermediate load, and wide-open throttle operation (acceleration) at varied speeds, mileage would decrease 9 percent for the low-emission carburetor vehicle using unleaded gasohol (Figure 10).

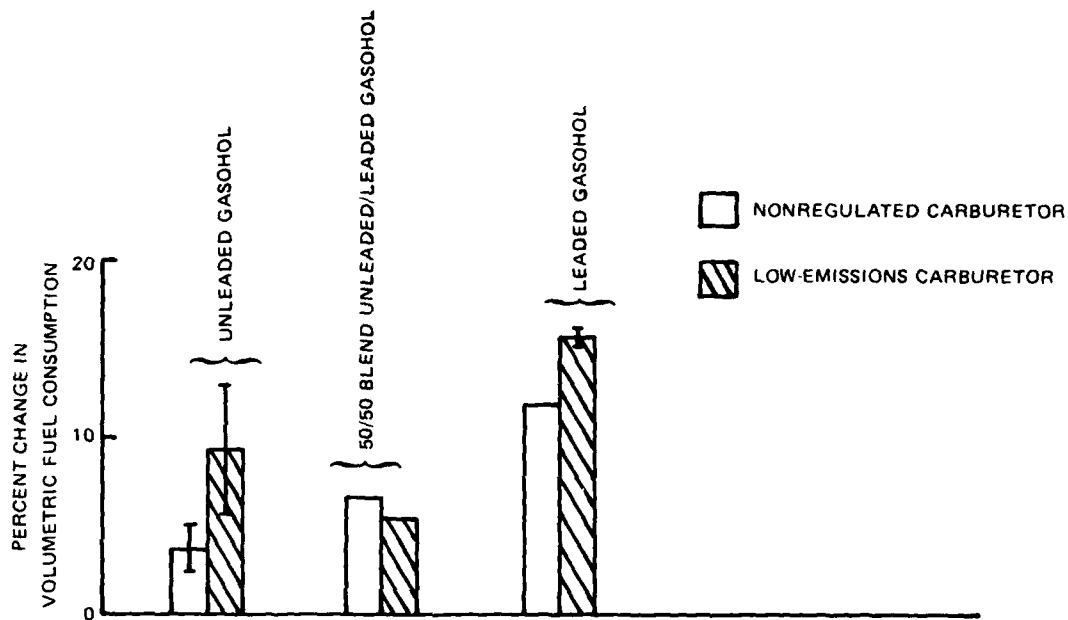


FIGURE 10. OVERALL AVERAGE OF VOLUMETRIC FUEL CONSUMPTION

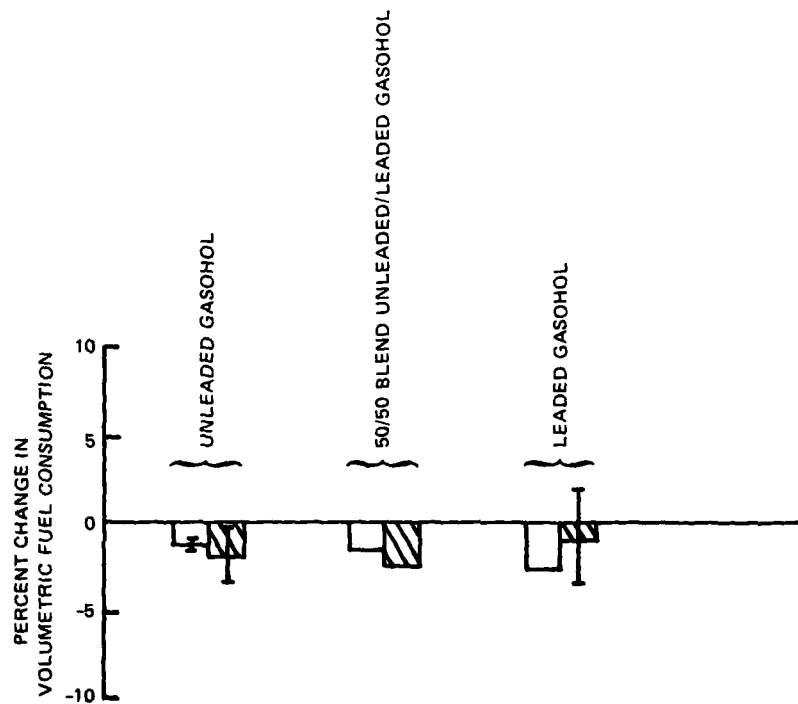


FIGURE 11. WIDE-OPEN THROTTLE AVERAGES OF VOLUMETRIC FUEL CONSUMPTION OVER THE RPM RANGE

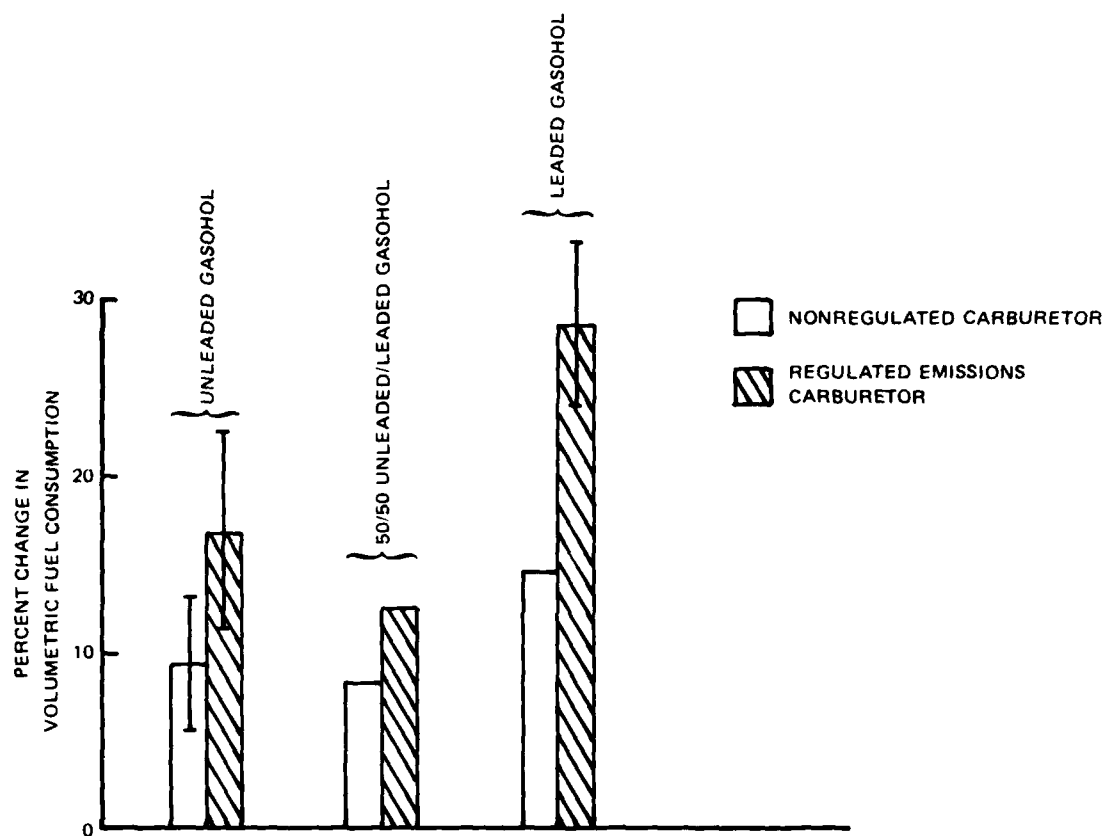


FIGURE 12. VOLUMETRIC FUEL CONSUMPTION AT 178 mm Hg MANIFOLD VACUUM AVERAGED OVER THE RPM RANGE

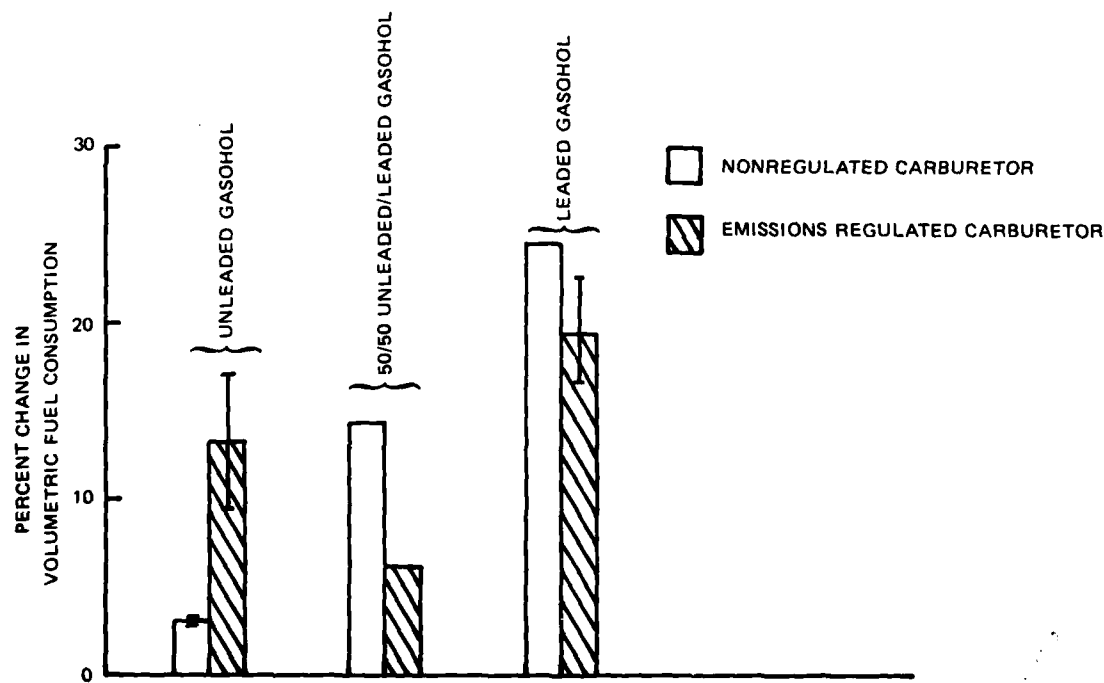


FIGURE 13. VOLUMETRIC FUEL CONSUMPTION AT 358 mm Hg MANIFOLD VACUUM AVERAGED OVER THE RPM RANGE

If the vehicle were equipped with the pre-1975 carburetor, then the decrease in mileage would be 3 percent. On the highway, the results would improve for both vehicles. Figure 11 indicates a 1 to 2 percent increase in mileage for wide-open throttle operation. The road load data in Appendix B indicates that roughly 60 mph is wide-open throttle. Finally, a mix of on-post and highway use may result in no change of the mileage being observed.

The 45/45/10 blend of unleaded/leaded/ethanol resulted in an increase of 5% volumetric fuel consumption, averaged over the three load conditions as compared to the base fuel. There was a distinct difference in fuel consumption between the carburetors at the light load condition (Figure 13). At this condition the nonregulated emissions carburetor resulted in an increase of 14% volumetric fuel consumption as compared to 5% for the same fuel but using the low emissions carburetor. This fuel resulted in the best fuel economy for the M191 when using the low-emissions carburetor.

The leaded gasohol fuel resulted in the poorest overall fuel consumptions, except at wide open throttle. Fuel consumption at wide open throttle was similar to the other fuels, showing a slight improvement of 3%. At part throttle, the fuel consumption was 28% greater than the base fuel. At the light load condition 20% poorer fuel economy was observed. This fuel resulted in the worst fuel economy as compared to the other test fuels.

B. Simulated Driveability Results

Two acceleration runs were made on unleaded regular and unleaded gasohol in the vehicle. Figure 14 illustrates the typical result. Throttle position, absolute manifold pressure, and rpm are shown versus time, which increases moving to the left. Starting at location one on the illustration, the initial opening of the throttle is made by the driver; after a slight hesitation, the engine rpm increases. At some point between one and two, the driver engages the clutch. At point two, the rpm decreases as the clutch loads the engine. The driver, sensing the rpm drop, increases the throttle opening. At point three, the clutch is fully engaged as the rpm steadily increases. Manifold pressure decreases as the throttle is held steady and the rpm rises. Manifold pressure is proportional to the load on the engine. The greater the manifold pressure, the greater the load on the engine. The

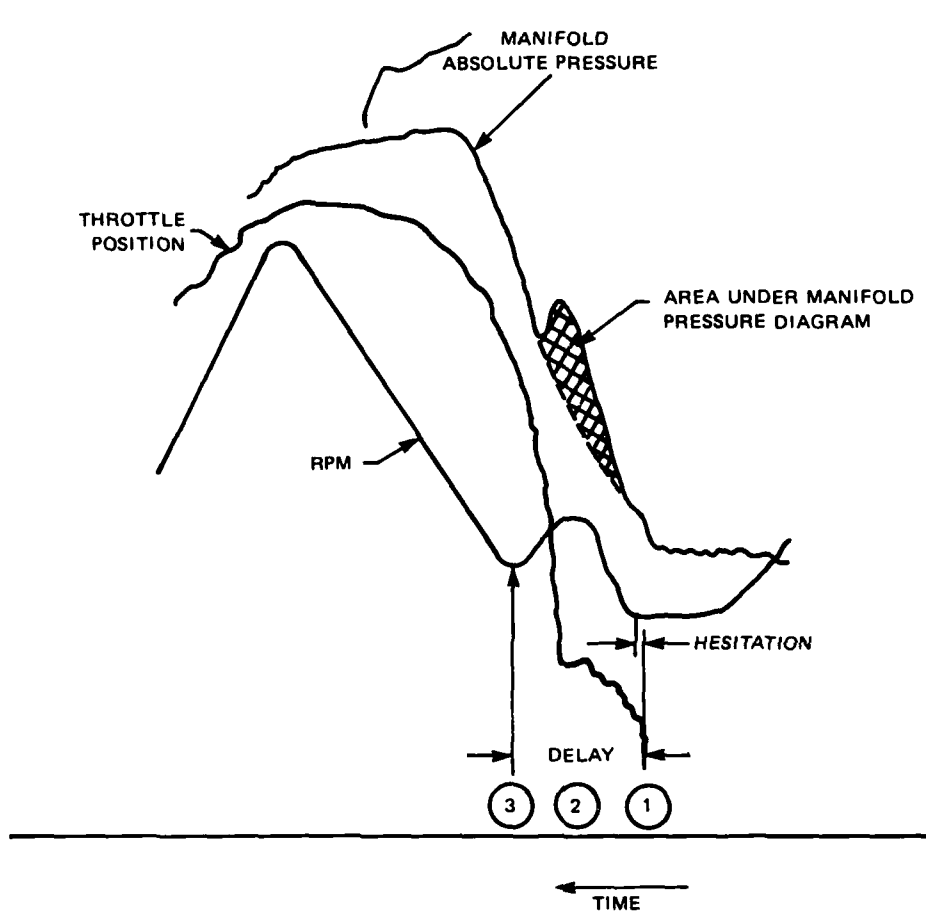


FIGURE 14. EXAMPLES OF DELAY, HESITATION AND THE AREA UNDER THE MANIFOLD PRESSURE CURVES

area beneath the curve represents the product of power and time (work). The accelerator pump on the carburetors used are controlled by manifold pressure. A rise in the manifold pressure results in the pump discharging an extra quantity of fuel in proportion to the change of the pressure. Therefore, the area below the curve is also proportional to the accelerator pump discharge. Delay, as shown in Figure 14, is the time from throttle opening to the clutch being fully engaged.

Hesitation, the area under the pressure curve, and delay, as defined in Figure 14, are plotted in Figures 15, 16, and 17, respectively. The data

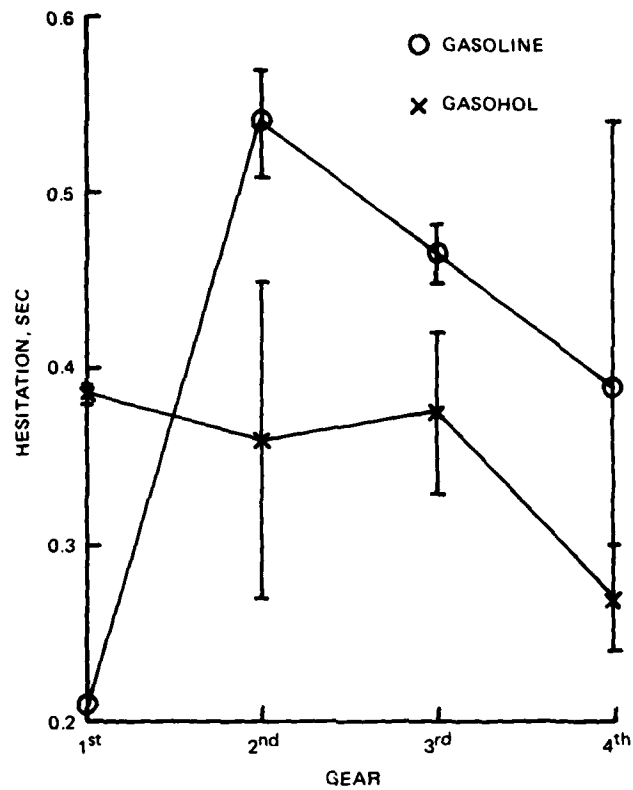


FIGURE 15. HESITATION OBSERVED DURING VEHICLE TESTS

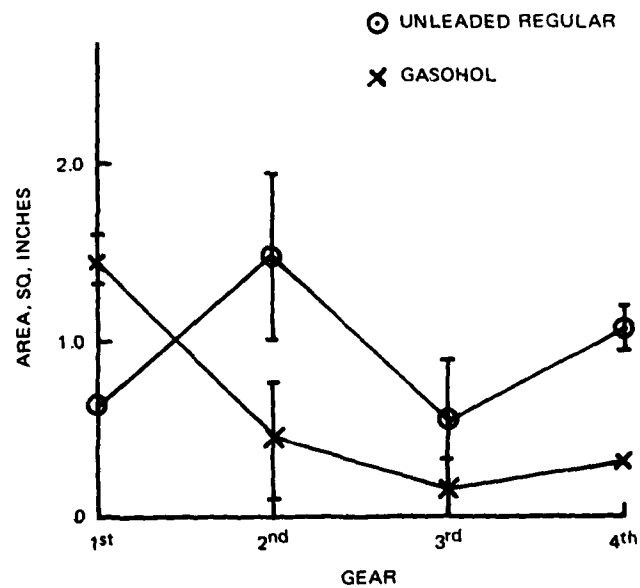


FIGURE 16. AREA MEASURED UNDER MANIFOLD PRESSURE CURVES

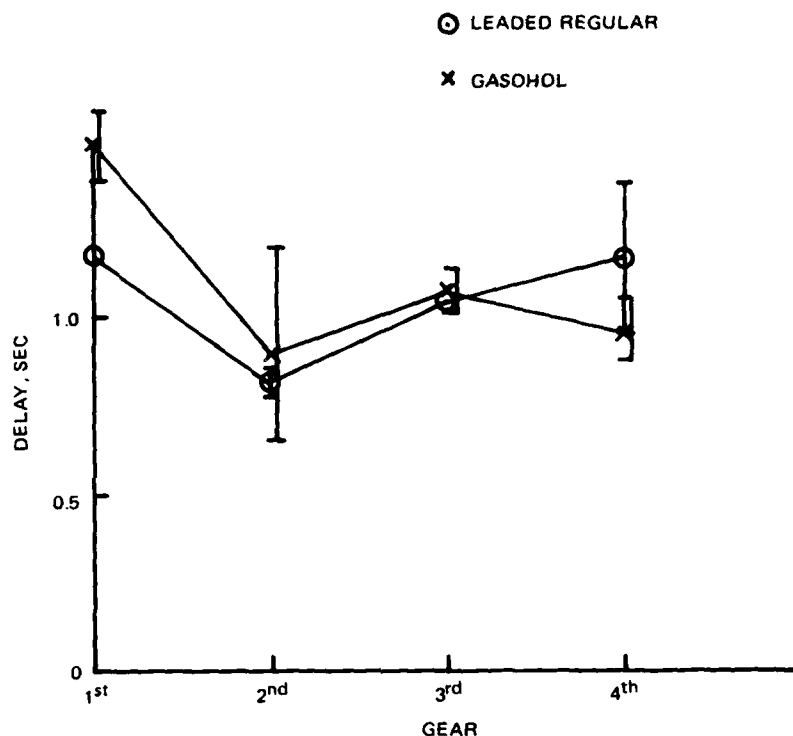


FIGURE 17. DELAY FROM THROTTLE OPENING TO STABILIZED ACCELERATION OBSERVED DURING VEHICLE TESTS

for each run are shown, as well as the average through which the lines are drawn. The tabulated data are contained in Appendix D. The gasoline had a greater hesitation than the gasohol except during first gear accelerations. Note that the area under the manifold pressure curve follows the same trend as the hesitation results. The total time to accelerate, namely, delay from initiation of acceleration to complete clutch engagement, did not vary among the fuels or the gears, except for first gear. Driver technique in the first gear differed from the other gears in that wide open throttle was not used. In the second through fourth gears, the driver used WOT after point two, illustrated in Figure 14. In first gear, a throttle setting of approximately 50 percent was used. The driver stated that he could not detect any differences in the driveability of the fuels. The ambient temperature was 29°C (85°F) during the vehicle tests.

Figure 18 illustrates a typical recorder trace for the engine-dynamometer accelerations. In this example, the throttle is snapped to the part or wide-open position. The runs with a slow opening of the throttle were unsuccessful. The friction in the throttle plate shaft resulted in erratic movement which was reflected in the manifold pressure and rpm data.

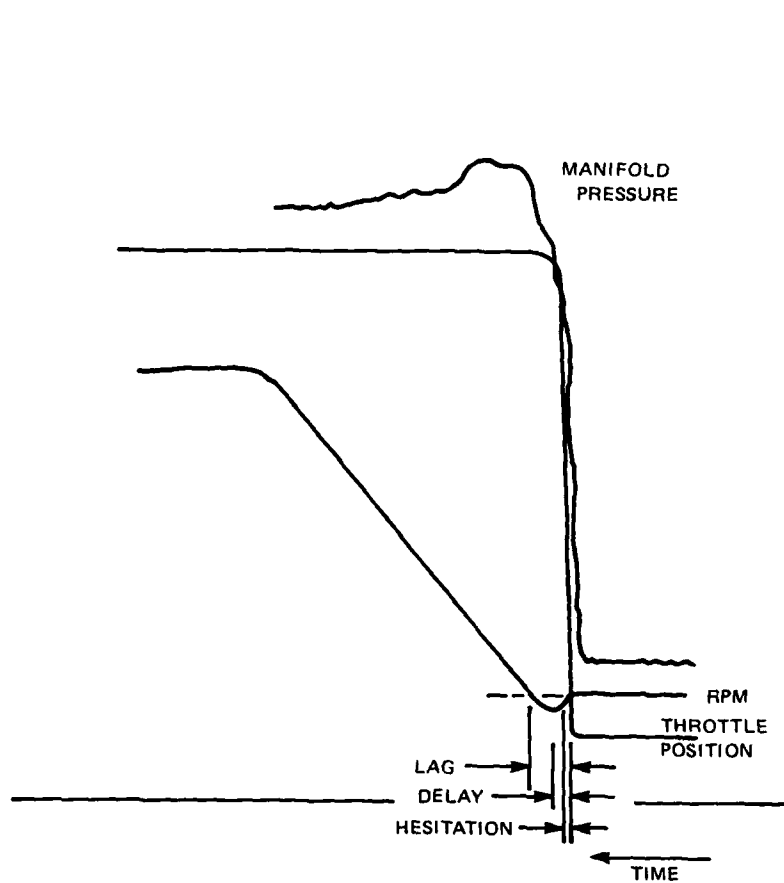


FIGURE 18. EXAMPLE OF LAG, HESITATION, AND DELAY OF THE RPM OBSERVED DURING THE DYNAMOMETER TESTS

Since damping of the road load simulator control loop was necessary to prevent oscillations, the amount of damping was experimentally determined. With the controller in each gear, the damping would be increased until the oscillations ceased. The dampings necessary for second, third, and fourth gear were excessive, lowering the time response of the controller. The responses for these gears were believed to be too slow to simulate the vehicle load; therefore, only first gear data were taken.

Figure 19 is a plot of the delay in rpm response to the throttle opening.

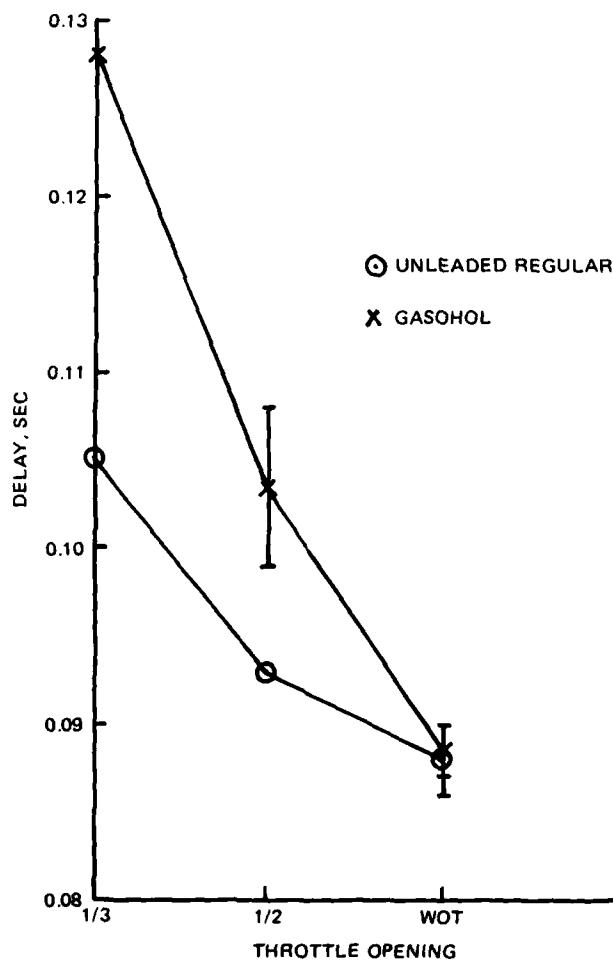


FIGURE 19. DELAY FROM THROTTLE OPENING TO RPM RESPONSE OBSERVED DURING DYNAMOMETER TESTS

Repeatability was good, with several of the repeat points being exactly the same as the first. The throttle was snapped open to three different positions which were one-third, one-half, and wide-open throttle (WOT). At the one-half throttle opening, the delay for the gasohol was roughly 0.1 second longer than the base fuel. A longer delay was also observed in the vehicle using gasohol and accelerating at approximately one-half throttle setting.

No hesitation, as illustrated in Figure 18, was observed for either fuel. Upon throttle opening, the rpm always decreased instantly.

Lag times, as shown in Figure 18, are plotted in Figure 20. Repeatability was not as good for this data as compared to the delay times. The differences between the fuels are of the same order as the error in the data. For both fuels, the lag time decreased in proportion to the throttle opening.

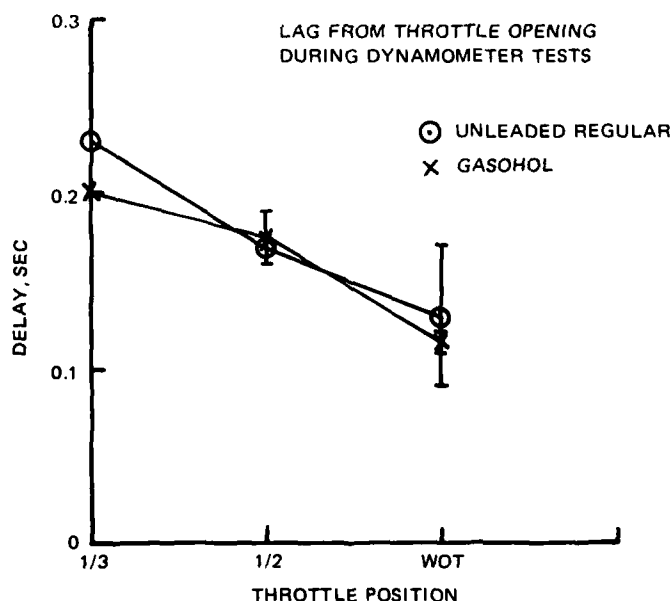


FIGURE 20. LAG FROM THROTTLE OPENING TO THE RECOVERY OF RPM OBSERVED DURING DYNAMETER TESTS

The difference in the front end volatility of these fuels may serve to explain these results. During first gear accelerations at approximately half-throttle, the vapor pressure differences in the fuel are not critical due to the high manifold vacuum. The partial pressure of the fuel is a large percentage of the total pressure in the manifold and slight differences are not critical. During WOT acceleration, the fuel partial pressure is the same, but the manifold total pressure is higher, resulting in a leaner mixture delivered to the cylinders. Therefore, during the first gear acceleration, the gasoline with the low vapor pressure performed satisfactorily.

The detection of differences between the fuels by these methods, not detected by the driver, is encouraging. More work needs to be done, however, first to develop a more sophisticated controller to include a simulated clutch to allow testing in the higher gears (or possibly use a flywheel and a real clutch to provide the inertial component of road load), and second, to define the relation of fuel properties to the observed dynamic engine response. Such data would then make it possible to predict vehicle transient response from fuel property data.

C. Endurance Testing

Table 5 summarizes the average operating conditions for the test. Differences in fuel consumption data, when compared to earlier testing (6), can be attributed to different richness settings in the carburetors. During the test, several unexpected shutdowns occurred in order to determine the cause of a loss of power after the 80th hour of operation. Examination revealed exhaust valve recession on cylinders 2 and 3. The valve recession continued to occur throughout the remainder of the testing. All other valves maintained their proper adjustment throughout the test. Post-test measurements revealed an approximate 0.1118 cm (0.0440 in.) recession for No. 2 exhaust and 0.1778 cm (0.070 in.) recession for No. 3 exhaust. It is felt that this level of exhaust valve recession is extremely high when the length of the endurance test is considered, and could have approached critical stages had the test lasted longer. Since the recession occurred on cylinders 2 and

TABLE 5. AVERAGE OPERATING CONDITIONS FOR
DYNAMOMETER EVALUATION WITH GASOHOL

Test No.	1
Piston Ring Type	Standard
Hours Completed	150
Total Oil Consumed, kg (lb)	1.85 (4.08)

2800 rpm mode

Torque, N-m (lb-ft)	125 (92)
Observed Power, kW (bhp)	36.8 (49.3)
Specific Fuel Consumption, kg/kW-hr (lb/bhp-hr)	0.299 (0.493)
Sump Temperature, °C (°F)	129 (265)

2000 rpm mode

Torque, N-m (lb-ft)	128 (94)
Observed Power, kW (bhp)	26.8 (35.9)
Specific Fuel Consumption, kg/kW-hr (lb/bhp-hr)	0.287 (0.472)
Sump Temperature, °C (°F)	115 (239)

Idle mode

Torque, N-m (lb-ft)	0
Observed Power, kW(bhp)	0
Sump Temperature, °C (°F)	88 (190)

3, it is concluded they were operating richer, thus hotter, due to maldistribution of the intake air-fuel charge. The amount of gum deposited on the intake valves of cylinders 2 and 3 indicate that these cylinders were running richer than cylinders 1 and 4 (see photos of Appendix F). Thus, by having cylinders 2 and 3 running hotter and richer than 1 and 4, it is concluded that this led to the increased wear of the exhaust valve seats. It is felt that this may be a fuel-related effect; however, at this time insufficient data exist to arrive at any valid conclusions.

Used oil analyses indicate that no major differences exist in the oil degradation rate between the unleaded fuel and gasohol except for TBN. An examination of the total acid number reveals approximately the same trends and magnitudes over the test period between the two fuels in the L-141 engine

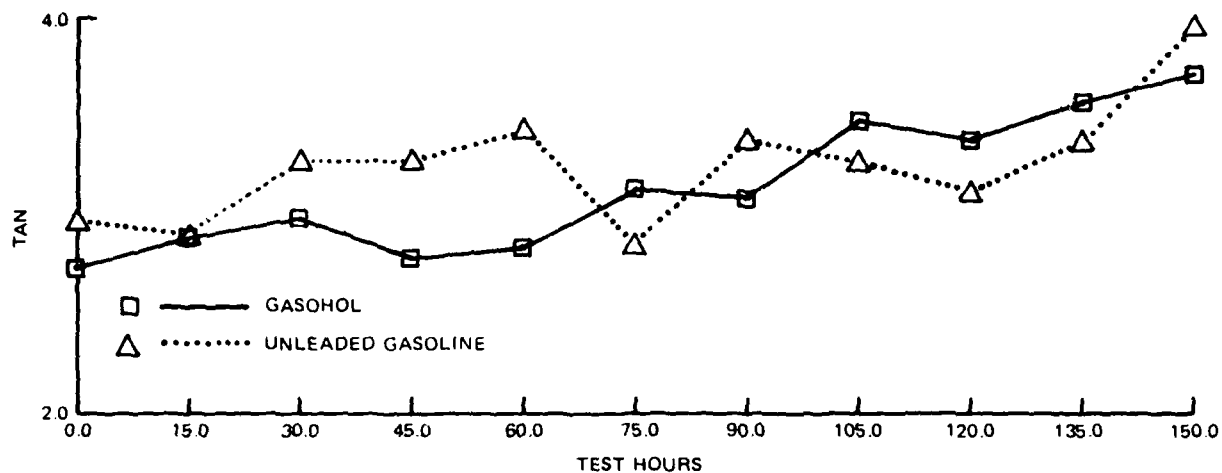


FIGURE 21. CHANGE IN TAN FOR GASOHOL AND UNLEADED GASOLINE
DYNAMOMETER EVALUATION

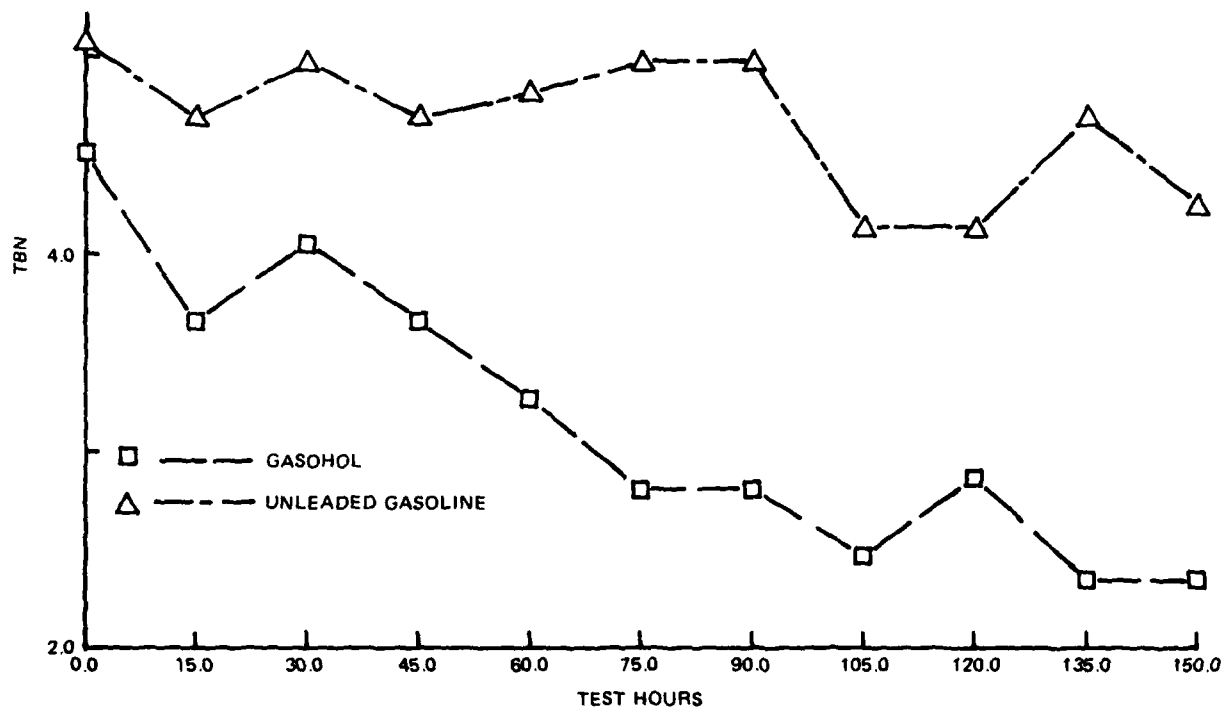


FIGURE 22. CHANGE IN TBN FOR GASOHOL AND UNLEADED GASOLINE
DYNAMOMETER EVALUATION

(Figure 21). However, the total base number shows a decrease of 2.17 for gasohol, versus a decrease of 0.84 base numbers for the unleaded gasoline (Figure 22). This seems to indicate that the gasohol is degrading the lubricant overbase additive package, due to an increase in acidic combustion products. The depletion of the base number is a trend associated with alcohol fuels, noted in previous work done at AFLRL(7). The magnitude of the percent viscosity changes over the 150 hours is relatively small, being 6 percent for gasohol and 14 percent for the unleaded gasoline. No conclusions can be made about the oil degradation rate based on the change in viscosity over the test duration (Figure 23).

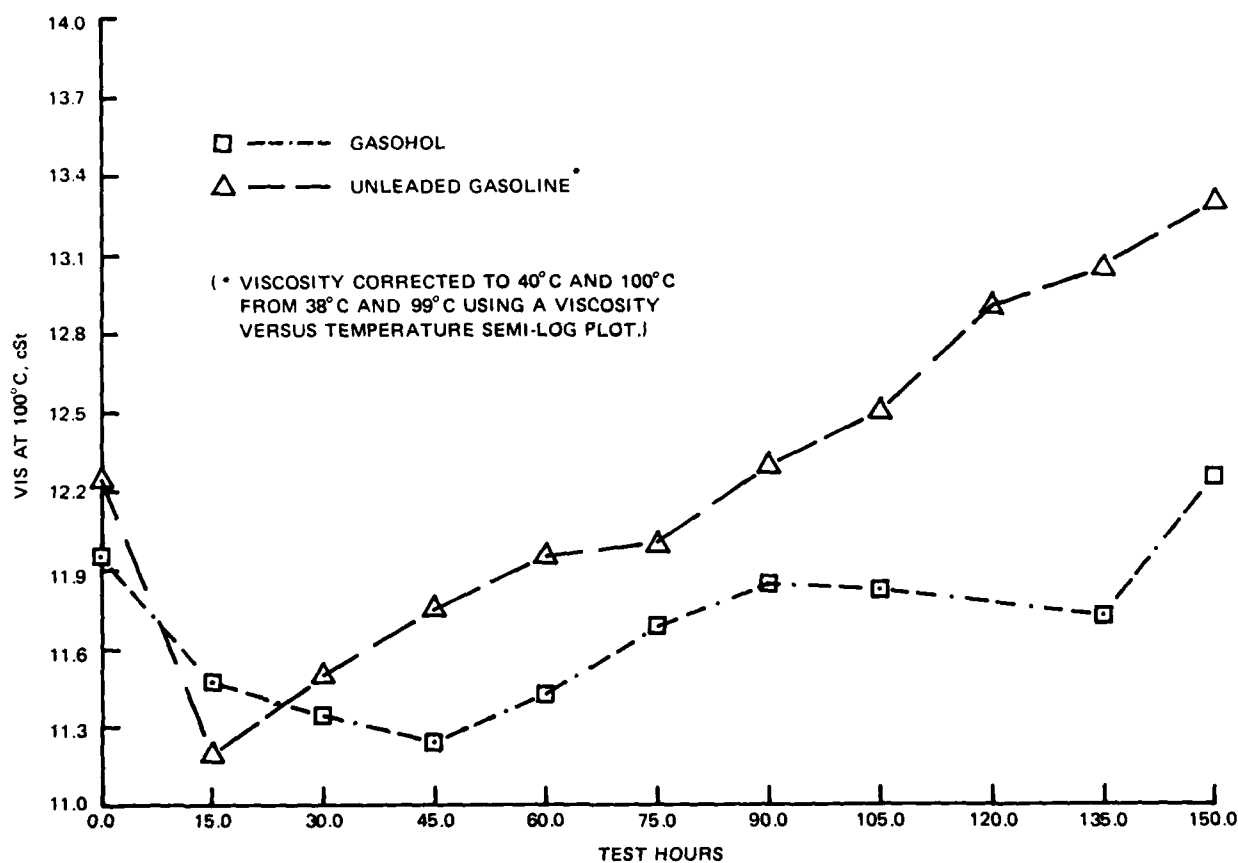


FIGURE 23. ENGINE OIL VISCOSITY AT 100°C, cSt
DYNAMOMETER EVALUATION

A comparison of ring wear data between the two fuels reveals that there are negligible differences in ring end gap and side clearance data. The piston and cylinder bore measurements indicate no additional wear with the gasohol fuel. Deposit ratings on the pistons indicate that deposits were moderate, falling in the range of 95-115 when rated using the AFLRL-modified deposit rating method. This method assigns a demerit rating ranging from a clean of 0 to as much as 700 conceivable for a totally carbon-encrusted piston. The increased oil consumption over the test period is the probable cause of the increased piston deposits. Detailed oil analysis data, measurement data, deposit ratings, and photos are given in Appendix F. Appendix G is the data applicable from previous AFLRL work (6), used for comparison purposes with the gasohol fuel.

D. Gasohol Evaluation in LDT-465-1C

The attempts at starting the LDT-465-1C with AL-10450-G + 10 percent ethanol proved that the 16 cetane number fuel was adequate for starting the engine at the ambient temperature noted in Table 6. The engine stumbled slightly until smooth idle was attained, then ran smoothly. After a smooth idle was attained, the rack was fully opened, and a load applied to the engine. The engine accelerated smoothly without hesitation to 1600 rpm and full load, which reached a stable 360 lb-ft.

TABLE 6. SUMMARIZATION OF LDT-465-1C
COLD STARTS WITH GASOHOL

<u>Gasohol Cetane No.</u>	<u>Starting Temp.</u>	<u>Qualitative Crank Time</u>	<u>Time to Smooth Idle (Min.)</u>	<u>% of DF-2 Power Obtained</u>
16	52°F	Normal	0.75	88
13	40°F	Long	4.0	83
12	60°F	No Start	---	---

The gasohol made with AL-10257-G + 10 percent ethanol appeared to be on the lower limit for the cetane requirements of the LDT-465-1C, at a cetane number of 13. During the trials, an unusually long time was required for cranking, with the engine missing and surging after eventually starting. The engine ran poorly, showing characteristics indicative of a low-cetane number fuel, i.e., surging and missing, and requiring almost four minutes before a smooth idle was attained. Upon acceleration to a full-load condition, the engine hesitated and stumbled. Although requiring an abnormally long time to attain full load, the engine produced a sporadic 340 ft-lb of torque.

During the purging procedure with the 12-cetane number fuel, the LDT-465-1C engine failed to run. Severe surging and missing were evident. The engine was then warmed up at full load with a diesel fuel and then switched to the gasohol. At this point, the engine output dropped to a minimal level with severe roughness. The dynamometer was used to motor the LDT-465-1C up to speed, then switched into the absorbing mode. Once again, the engine failed to run on the gasohol made with AL-8836-G and 10 percent ethanol. Because the "hot" engine would not function with this fuel, "cold" start procedures were not initiated. The results are summarized in Table 4.

V. CONCLUSIONS

- Under some operating conditions, the M141 engine performance is improved by the use of gasohol.
- Thermal efficiency at heavy load conditions is improved by 5 percent for all fuel/ carburetor combinations tested.
- Light and intermediate-load performance deterioration will result in a decrease in mileage during on-post operation using gasohol.
- The older, nonemission-regulated carburetor is better suited for unleaded gasohol use.
- The 45/45/10 blend of unleaded/leaded/ethanol resulted in the best gasohol performance for the low emissions carburetor.
- Leaded gasohol resulted in very poor engine operation at light and intermediate load conditions.
- Gasohol does not affect the maximum power developed significantly.
- Based upon engine oil analysis, no significant change in engine wear rates was noted.
- Differences in the engine response operating on Gasohol were detected during the dynamometer and vehicle tests, but during the vehicle tests the driver did not detect the slight differences.
- The relatively short endurance test indicates that more frequent oil drain procedures may be required due to the trend of TBN depletion during operation with gasohol. TBN depletion of the engine oil may be attributed to acidic combustion byproducts from the gasohol.
- Gasohol is of inadequate cetane number to sustain normal engine operation in the LDT-465-1C, a member of the LDT-465 family of multifuel engines.

VI. RECOMMENDATIONS

- Gasohol can be used in the M141 vehicle with no special modifications, but the potential user should make an assessment of the effects gasohol will have on vehicle fuel mileage. The conclusions of this report indicate that a decision to use gasohol in the M151 vehicle should take into consideration the vehicle's usage pattern (on-post or freeway), which carburetor is installed, and the type of gasohol mixture (unleaded, 45/45/10 or leaded). The differences observed in engine performance when using gasohol as compared to gasoline appear to be mostly due to stoichiometry. These differences can be corrected by carburetor jet changes. Therefore, further work is recommended to determine the best carburetor jetting for gasohol.
- More work needs to be done, in simulated driveability, first to develop a more sophisticated controller to include a simulated clutch to allow testing in higher gears, and second, to define the relation of fuel properties to the observed dynamic engine response. Such data could be used to predict vehicle transient response from fuel property data.
- With the use of gasohol in the L-141 engine, the frequency of oil drain procedures is recommended to be increased due to TBN depletion of the oil.
- The use of gasohol for the operation of the LDT-465 family of multifuel engines is not recommended.

VII. REFERENCES

- (1) "1973 Driveability Instrumentation Tests", CRC Report No. 489, November, 1976.
- (2) Federal Specification VV-G-1690B, "Gasoline, Automotive, Leaded or Unleaded," July 1978.
- (3) Purchase Description ME-102a, "Gasohol, Automotive, Unleaded," February 1980.
- (4) U.S. Military Specification MIL-L-2104C, "Lubricating Oil, Internal Combustion Engine, Tactical Service," November 1970.
- (5) U.S. Military Specification MIL-L-46152B, "Lubricating Oil, Internal Combustion Engine, Administrative Service," January 1981.
- (6) E. C. Owens, S. J. Lestz, and R. D. Quillian, Jr., "Never Drain Engine Oil Technology, Phase II", U. S. AFLRL Interim Report No. 72, prepared by U. S. Army Fuels and Lubricants Research Laboratory, Gov. Accession No. AD A023256, October 1975.
- (7) H. W. Marbach, Jr., E. A. Frame, E. C. Owens, and D. W. Naegeli, "The Effects of Alcohol Fuels and Fully Formulated Lubricants on Engine Wear," SAE No. 811199, presented at Fuels and Lubricants meeting, Tulsa, OK, October 1981.

APPENDIX A
CARBURETOR SPECIFICATIONS

APPENDIX A. CARBURETOR SPECIFICATIONS

	Zenith No. 13841 <u>No. 12848</u>	Zenith No. 13660 <u>Low-Emission Carburetor</u>
Air Nozzle, mm	26	26
Main Jet, mm	30	28
Idle Jet, mm	12	15
Power & Acceleration		
Jet, mm	12	24
Power Jet Valve, mm	10	10
Idle Air Bleed, mm	28	43
Well Vent, mm	16	40
Fuel Valve Seat, mm	30	30
Float Level, mm	12.0-14.0	13.5-15.5

CARBURETOR ADJUSTMENT PROCEDURE

General

This procedure is predicated upon other aspects of the engine being within operational tolerances, such as valve lash, timing, point dwell setting or spark plug condition and gap setting. If after carburetor adjustment, the engine still fails to operate properly (i.e., loss of power at higher speeds, roughness, etc.), the fault probably lies within the carburetor.

In this situation, the carburetor should be replaced and the new carburetor checked for adjustment according to the procedure. The replaced carburetor should be retained for subsequent repair. If a replacement carburetor is not available, then the carburetor should be disassembled, cleaned, and adjusted per TM 9-2320-218-34 (Jan 72), page 5-17 through 5-20. For information, a carburetor repair kit and procedures are being developed for release to the field.

Details

The following procedure is to be used for the adjustment of the new M151A2 EPA Certified Emission Control Carburetor, FSN 2910-255-0724. This procedure does not require the use of the vehicle emission analyzer but does require the use of a tester dwell tachometer, FSN 4910-788-8549, a prick punch, a standard screwdriver, and a 5/64 Allen wrench.

The procedure is as follows:

1. Ensure that the engine timing and dwell are properly adjusted. (Reference TM 9-2320-218-20, dated September 1971, Page 2-129, Paragraph 2-71).
2. Using the prick punch, remove the sealing plug that covers the mixture adjusting screw.
3. Warm the engine to normal operating temperature.
4. Connect the tachometer for reading engine rpm.

(NOTE: ENSURE THAT THE TACHOMETER IS IN PROPER CALIBRATION PRIOR TO MAKING THE ADJUSTMENT)

5. Turn the idle adjustment screw (see attached illustration) until the engine reaches 700 rpm.
6. Use the Allen wrench to back off (counterclockwise) the mixture adjusting screw until the idle rpm no longer increases.
7. Turn the idle adjusting screw out until the engine reaches 700 rpm.
8. Turn (clockwise) the mixture screw until the rpm reaches 640 to 650 rpm.

9. Disconnect the tachometer and install a new sealing plug (MS-9379-2). If unable to obtain sealing plugs, seal the mixture screw with Dow Corning Silicone Rubber, FSN 8040-914-7013 or FSN 8040-833-9563. It is available through GSA.

This procedure will retain the vehicle emissions within the EPA-established standard.

APPENDIX B
SIMULATED DRIVEABILITY APPARATUS

APPENDIX B

Simulated Driveability Apparatus

Figure B-1 is a block diagram outlining the simulated driveability experiment. The Dialog¹ 1022 dynamometer controller was operated in torque control mode, utilizing an external set point voltage. In this mode, the controller will vary the excitation current as necessary to minimize the error between the external set point voltage and the torque feedback signal. The external set point voltage can range between 0 to 10 volts. The controller's dynamic response was optimized according to the manufacturer's recommendations. The set point voltage was calibrated to yield a factor of $15 \frac{\text{ft-lb}}{\text{volt}}$.

The 60-tooth wheel was mounted on the dynamometer shaft. A magnetic pick-up sensed the passage of the teeth. An Action Pak Model 7010 was used to convert the magnetic sensor output into a voltage ranging from 0 to 10 volts at $\frac{1 \text{ volt}}{1000 \text{ rpm}}$. The road load simulator accepted this voltage and, based upon the signal level and its rate of change, output to the dynamometer controller a torque set point voltage representative of the torque requirements of the M151 vehicle.

Figure B-2 outlines the circuitry of the simulator. The circuitry determines the torque setpoint voltage as two separate components; the steady state component and the transient or inertial component. The steady-state component arises due to tire rolling resistance and aerodynamic losses. The inertial component is due to the mass of the vehicle resisting changes in velocity.

The steady-state component of the road load torque requirement was determined by vehicle testing. The vehicle was equipped with a manifold vacuum

¹ A list of equipment, manufacturer, and description is contained in Appendix C.

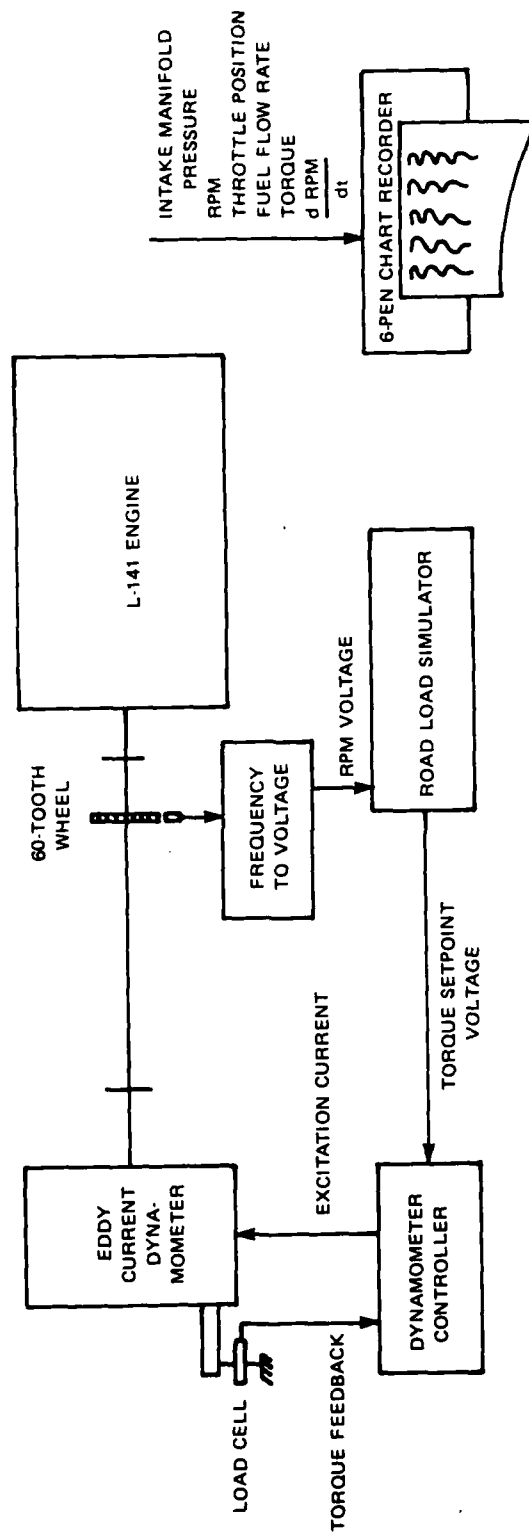


FIGURE B-1. SIMULATED DRIVEABILITY BLOCK DIAGRAM

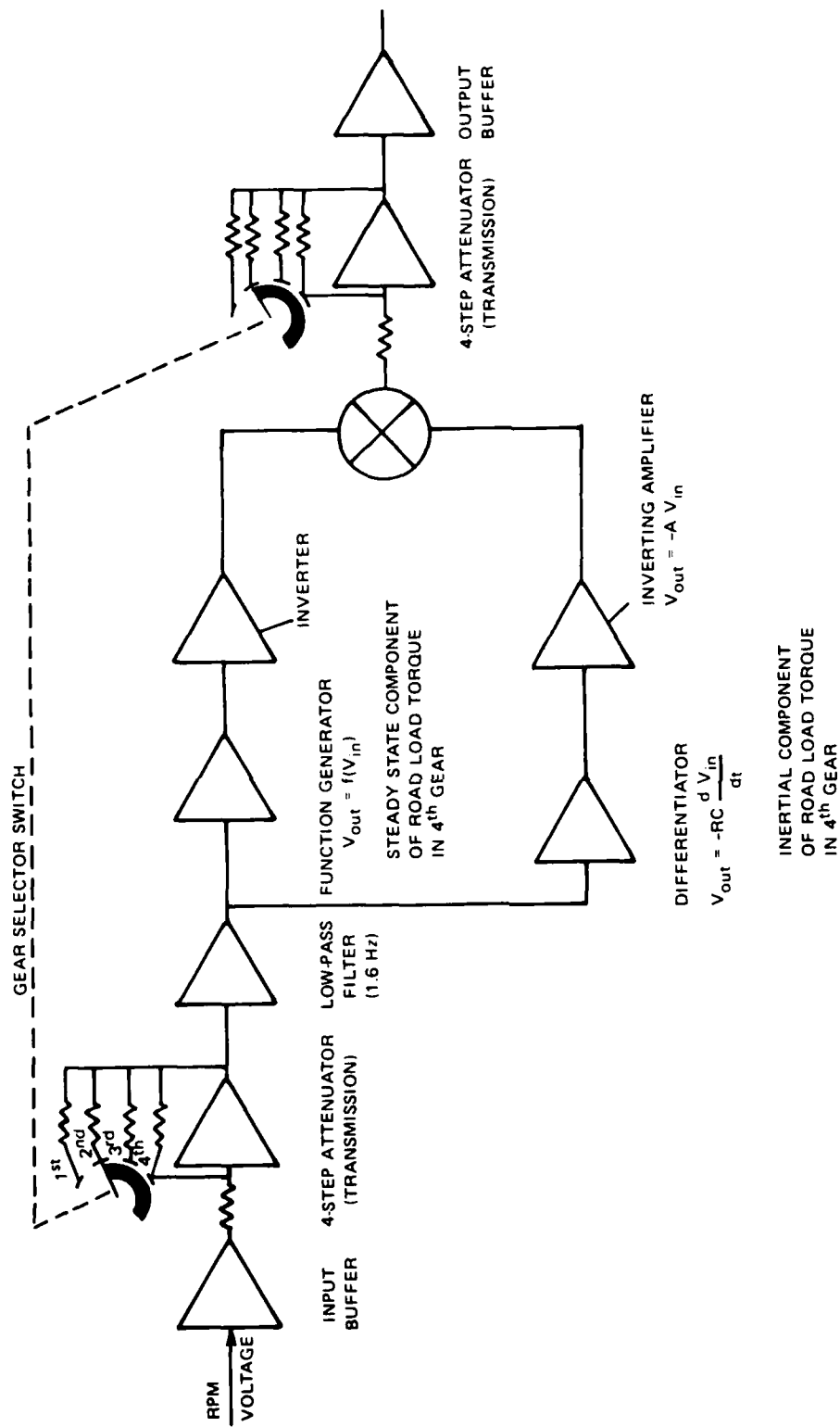


FIGURE B-2. BLOCK DIAGRAM OF ROAD LOAD SIMULATOR

gage and tachometer. Loaded to 1090 kg (2400 pounds), the vehicle was driven at a steady speed of 32, 48, 64, 72 and 80 km/hr (20, 30, 40, 45, 50 mph) in fourth gear, noting the manifold vacuum and engine rpm. The tests were then repeated in the opposite direction to cancel the effects of road grade and wind.

The vehicle carburetor was then mounted on the L-141 engine located in the dynamometer test cell. Operating the engine on the dynamometer at the average manifold vacuum and rpm observed during the vehicle testing, the dynamometer torque was noted. The results are plotted in Figure B-3. The horsepower versus vehicle speed was calculated and plotted in this figure also. Note that the torque requirement decreases with rpm until approximately 2500, then rises sharply. The rpm and torque required curves are for fourth gear operation.

The function generator (Figure B-2) was programmed to provide an output voltage, representing the steady-state torque, for the input voltage which was proportional to the engine rpm. The function generator consisted of a multiple gain operational amplifier. The circuit could approximate the torque required curve by four straight line segments. The initial segment has a negative slope. The next three segments were positive slopes. The individual slopes and breakpoints were controlled by variable resistors. The breakpoint calibrations are given in Table B-1.

TABLE B-1. CALCULATED INPUT AND OUTPUT VOLTAGES
OF FUNCTION GENERATOR

km/hr	mph	rpm	Torque		V_{in}	V_{out}	
			N-m	ft-lb			
0	0	0	-	-	2.0	3.25	Note 1, 2
32	(20)	1130	107.0	(79.5)	4.26	4.70	
48	(30)	1695	92.2	(68.2)	5.39	5.45	
64	(40)	2260	80.1	(59.3)	6.52	6.05	Note 2
76	(45)	2545	86.2	(63.8)	7.65	5.75	Note 2
80	(50)	2825	109.6	(81.1)	8.21	4.59	
					10.0	2.00	Note 1, 2

Note 1: This point was obtained by extrapolation.

Note 2: This point was used to define a breakpoint and setpoint.

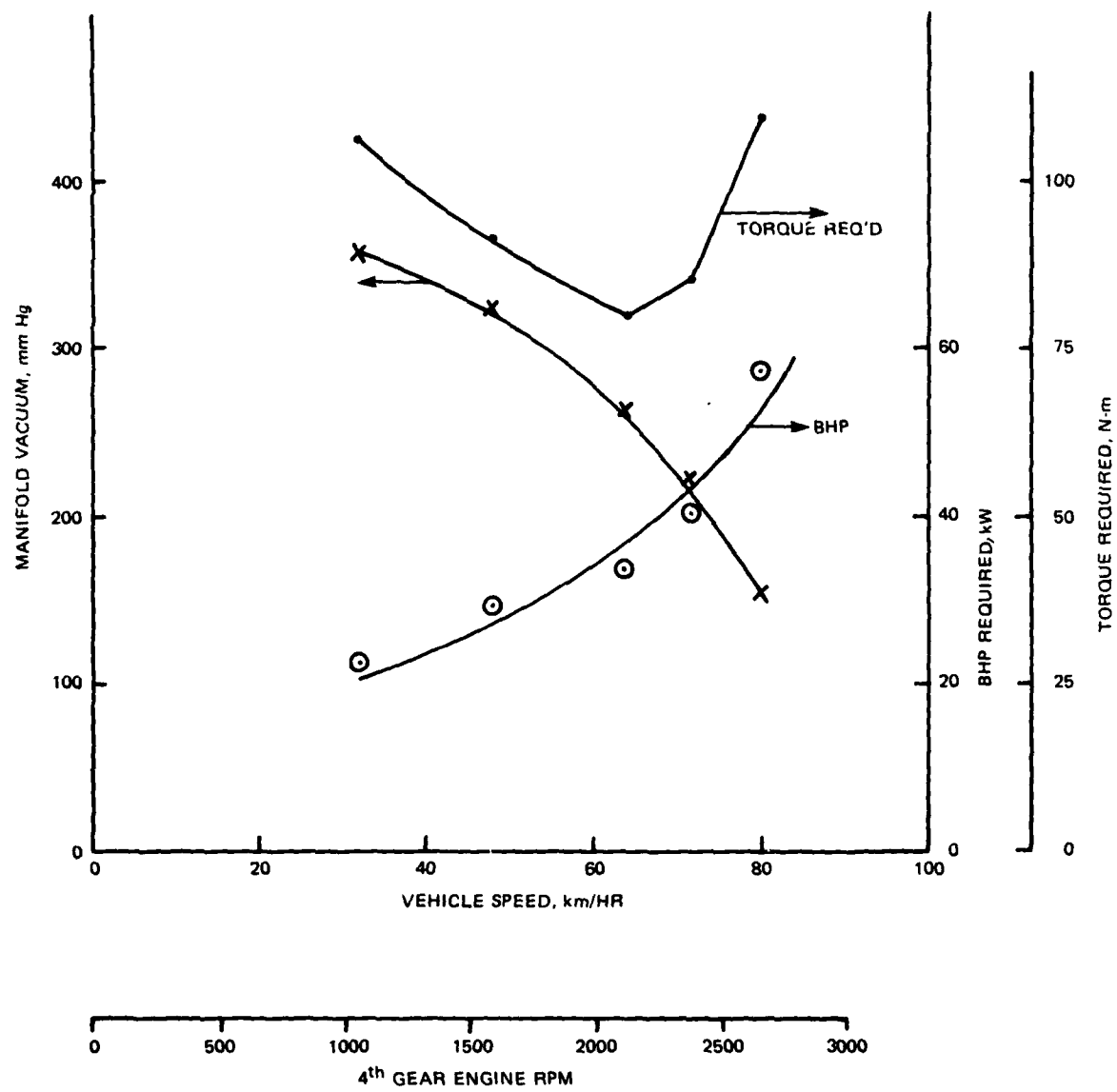


FIGURE B-3. M151 VEHICLE ROAD LOAD

APPENDIX C
EQUIPMENT LIST

PRECEDING PAGE BLANK-NOT FILMED

APPENDIX C

EQUIPMENT LIST

<u>Item</u>	<u>Manufacturer</u>
Model 1024 Dynamometer Controller	Digalog Corp. Ventura, CA
Model AP 9051 Strain Gage Amplifier	Action Instruments Co., Inc. San Diego, CA
Model AP 7010 Frequency-to- Voltage Converter	Action Instruments Co., Inc. San Diego, CA
Model P704-0001 Pressure Transducer	Schaevitz Pennsauken, NJ

APPENDIX D
SIMULATED DRIVEABILITY DATA

PRECEDING PAGE BLANK-NOT FILMED

APPENDIX D. SIMULATED DRIVEABILITY DATA

Vehicle Tests Raw Data

	<u>Delay, sec</u>	<u>Hesitation, sec</u>	<u>Area Under Manifold Pressure Curve, sq in.</u>
	<u>First gear</u>		
Unleaded	1.17	0.21	0.62
Unleaded	1.59	0.38	1.60
Gasohol	1.38	0.39	1.32
	<u>Second gear</u>		
Unleaded	0.78	0.57	1.96
	0.84	0.51	1.00
Unleaded	1.14	0.45	0.10
Gasohol	0.66	0.27	0.78
	<u>Third gear</u>		
Unleaded	1.05	0.45	0.90
	1.05	0.48	0.17
Unleaded	1.02	0.33	0.32
Gasohol	1.14	0.42	0.00
	<u>Fourth gear</u>		
Unleaded	0.96	0.24	0.96
	1.38	0.54	1.19
Unleaded	0.87	0.24	0.30
Gasohol	1.05	0.30	0.35

Engine Dynamometer Tests Raw Data

	<u>Lag, sec</u>	<u>Delay, sec</u>
<u>One-third throttle position</u>		
Unleaded	0.23	0.105
	0.23	0.105
Unleaded Gasohol	0.20	0.128
<u>One-half throttle position</u>		
Unleaded	0.17	0.093
	0.17	0.093
Unleaded Gasohol	0.19	0.108
	0.16	0.099
<u>Wide-open throttle position</u>		
Unleaded	0.17	0.090
	0.09	0.086
Unleaded Gasohol	0.12	0.087
	0.11	0.090

APPENDIX E
DYNAMOMETER TEST CYCLE

APPENDIX E. DYNAMOMETER TEST CYCLE

Cycle Phase

Controlled Variables	1	2	3*
Time per cycle, min	30	60	30
Engine speed, rpm	2000	2800	600
Load, N-m (ft-lb)	129 (95)	127 (94)	0
Water temp., °C (°F)	82 (180)	82 (180)	38 (100)

*Every fourth idle cycle omitted for oil sampling and consumption measurements.

This cycle was repeated for 16 hours, followed by an 8-hour shut-down. This 24-hour cycle is repeated as necessary to obtain the desired test duration. Of the total 24 hours, only 15 hours are to be counted as engine operating time.

Cycle Significance:

Based on road load measurements from an M151 vehicle loaded to its rated cross-country capacity of 250 kg (550 lb), the 2000-rpm phase was intended to represent 56 kilometers per hour (35 mph) high-load operation, while the 2800-rpm period was to represent 80 kilometer per hour (50 mph) level road operation. Based on this, a 100-hour period of operation would represent 5430 kilometers (3375 miles) traveled.

APPENDIX F
150-HOUR ENDURANCE TEST RESULTS

PRECEDING PAGE BLANK-NOT FILMED

APPENDIX F. TEST RESULTS

Test 1
150 hours

Summary of Operating Conditions

<u>2800 rpm mode</u>	<u>Avg</u>	<u>Min</u>	<u>Max</u>
Torque, N-m (lb-ft)	125 (92)	116 (86)	129 (95)
Power, OBS, kW (bhp)	36.8 (49.3)	34.1 (45.7)	37.8 (50.4)
Specific Fuel Cons., kg/kW-hr (lb/bhp-hr)	0.299 (0.493)	0.288 (0.475)	0.323 (0.532)
Sump Temperature, °C (°F)	129 (265)	119 (247)	132 (271)
Manifold Vacuum, kPa (In. Hg)	5.7 (1.7)	4.4 (1.3)	7.0 (2.1)

<u>2200 rpm mode</u>	<u>Avg</u>	<u>Min</u>	<u>Max</u>
Torque, N-m (lb-ft)	128 (94)	126 (92.8)	129 (94.5)
Power, OBS, kW (bhp)	26.8 (35.9)	26.3 (35.3)	26.9 (36)
Specific Fuel Cons., kg/kW-hr (lb/bhp-hr)	0.287 (0.472)	0.262 (0.431)	0.314 (0.516)
Sump Temperature, °C (°F)	115 (239)	110 (230)	119 (247)
Manifold Vacuum, kPa (In. Hg)	5.8 (1.7)	4.1 (1.2)	7.0 (2.1)

<u>600 rpm mode</u>	<u>Avg</u>	<u>Min</u>	<u>Max</u>
Torque, N-m (lb-ft)	0	0	0
Power, OBS, kW (bhp)	0.0	0.0	0.0
Sump Temperature, °C (°F)	88 (190)	78 (172)	95 (203)
Manifold Vacuum, kPa (In. Hg)	67.5 (19.8)	64.1 (18.8)	70.9 (20.8)

Test 1
150 hours
Gasohol
Used Oil Analysis

Test Hour	Viscosity, cSt		Total Acid No.	Total Base No.	Insolubles, %		Wear Metals, ppm						
	40°C	100°C			Pentane "B"	Toluene "B"	Fe	Cu	Cr	Pb	Sn	Si	Mg
New	103.39	11.95	2.73	4.51	0.01	0.01	-	-	-	-	-	-	-
15	95.10	11.47	2.88	3.66	0.03	0.02	-	-	-	-	-	-	-
30	90.04	11.34	2.98	4.05	0.05	0.04	34	12	-	-	-	-	-
45	93.94	11.24	2.78	3.66	0.07	0.05	45	7	-	-	-	-	-
60	95.26	11.42	2.83	3.26	0.13	0.08	50	-	-	-	-	-	-
75	99.01	11.68	3.13	2.80	0.21	0.12	58	20	-	71	-	-	-
90	101.30	11.84	3.08	2.80	0.26	0.16	56	19	-	58	-	-	-
105	100.41	11.82	3.48	2.46	0.36	0.20	69	21	-	67	-	-	-
120	*	*	3.38	2.86	0.06	0.05	77	18	-	30	-	-	-
135	105.31	11.72	3.57	2.34	0.07	0.04	81	24	-	48	-	-	-
150	105.66	12.25	3.72	2.34	0.28	0.18	95	24	-	24	-	-	-

* Not enough sample to perform these tests

Test 1
150 hours
Oil Consumption

<u>Test Hours</u>	<u>Oil Consumed, kg (lb)</u>	<u>Sample Removed, kg (lb)</u>	<u>Oil Added, kg (lb)</u>
7.5	0	0	0
15	0.21 (0.50)	0.10 (0.24)	0.31 (0.74)
22.5	0	0	0
30	0.06 (0.14)	0.09 (0.22)	0.15 (0.36)
37.50	0.25 (0.60)	0	0.25 (0.60)
45	0	0.09 (0.22)	0.09 (0.22)
52.5	0	0	0
60	0	0.09 (0.22)	0.09 (0.22)
67.5	0	0	0
75	0.35 (0.84)	0.09 (0.22)	0.44 (1.06)
82.5	0	0	0
90	0	0.09 (0.22)	0.09 (0.22)
97.5	0	0	0
105	0	0.10 (0.24)	0.10 (0.24)
112.5	0.20 (0.49)	0	0.20 (0.49)
120	0	0.09 (0.22)	0.09 (0.22)
127.5	0	0	0
135	0	0.09 (0.22)	0.09 (0.22)
150	0	0.10 (0.24)	0.10 (0.24)

Initial fill 3.91 kg (8.60 lb)
 Final drain 3.27 kg (7.20 lb)
 Change in filter wt. 0.27 kg (0.60 lb)
 Total oil consumed 1.85 kg (4.08 lb)

APPENDIX F. PISTON RING MEASUREMENTS

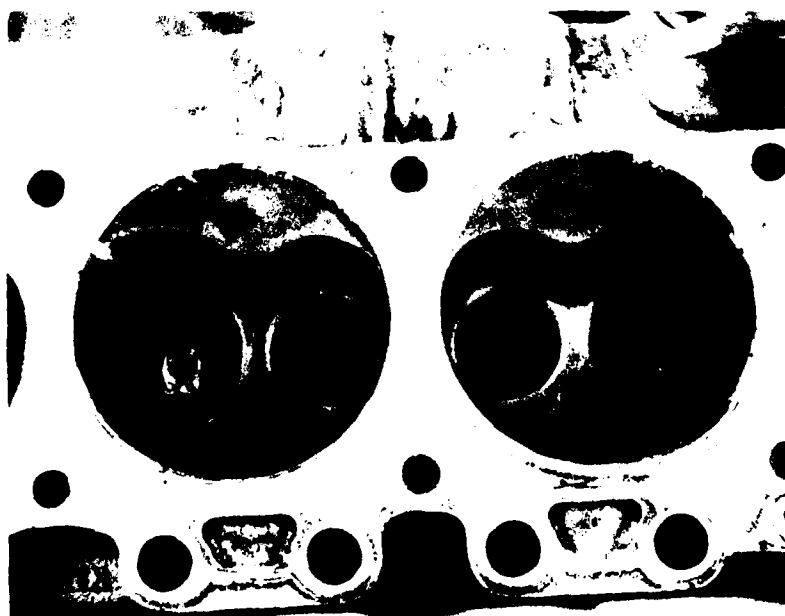
		End Gaps, cm (inches)			
		Piston Number			
Piston Ring		1	2	3	4
	before	0.051 (0.020)	0.048 (0.019)	0.051 (0.020)	0.048 (0.019)
	after	0.051 (0.020)	0.048 (0.019)	0.051 (0.020)	0.051 (0.020)
Second Ring	change	0	0	0	0.003 (0.001)
	before	0.041 (0.016)	0.043 (0.017)	0.041 (0.016)	0.038 (0.015)
	after	0.041 (0.016)	0.043 (0.017)	0.041 (0.016)	0.038 (0.015)
	change	0	0	0	0
		Side Clearance, cm (inches)			
		Piston Number			
Piston Ring		1	2	3	4
	before	0.005 (0.002)	0.005 (0.002)	0.005 (0.002)	0.005 (0.002)
	after	0.005 (0.002)	0.005 (0.002)	0.005 (0.002)	0.005 (0.002)
Second Ring	change	0	0	0	0
	before	0.005 (0.002)	0.005 (0.002)	0.005 (0.002)	0.005 (0.002)
	after	0.005 (0.002)	0.005 (0.002)	0.005 (0.002)	0.005 (0.002)
	change	0	0	0	0

APPENDIX F. PISTON AND CYLINDER BORE MEASUREMENTS

		Cylinder Bore, cm (inches)			
		Piston Number			
Measurement Location		1	2	3	4
Transverse	before	9.8478 (3.8771)	0.95 cm from top 9.8473 (3.8769)	9.8466 (3.8766)	9.8471 (3.8768)
	after	9.8476 (3.8770)	9.8476 (3.8770)	9.8468 (3.8767)	9.8468 (3.8767)
	change	-0.0003(-0.0001)	0.0003 (0.0001)	0.0003 (0.0001)	-0.0003(-0.0001)
Longitudinal	before	9.8468 (3.8767)	9.8476 (3.8770)	9.8476 (3.8770)	9.8461 (3.8764)
	after	9.8481 (3.8772)	9.8481 (3.8772)	9.8478 (3.8772)	9.8473 (3.8769)
	change	0.0013 (0.0005)	0.0005 (0.0002)	0.0003 (0.0001)	0.0013 (0.0005)
Transverse	before	9.8471 (3.8768)	5.24 cm from top 9.8455 (3.8762)	9.8458 (3.8763)	9.8455 (3.8762)
	after	9.8468 (3.8767)	9.8458 (3.8763)	9.8458 (3.8763)	9.8453 (3.8761)
	change	-0.0003(-0.0001)	0.0003 (0.0001)	0	-0.0003(-0.0001)
Longitudinal	before	9.8445 (3.8758)	9.8458 (3.8763)	9.8453 (3.8761)	9.8448 (3.8759)
	after	9.8453 (3.8761)	9.8463 (3.8765)	9.8458 (3.8763)	9.8458 (3.8763)
	change	0.0008 (0.0003)	0.0005 (0.0002)	0.0005 (0.0002)	0.0010 (0.0004)
Transverse	before	9.8473 (3.8769)	7.78 cm from top 9.8461 (3.8764)	9.8458 (3.8763)	9.8458 (3.8763)
	after	9.8476 (3.8770)	9.8461 (3.8764)	9.8458 (3.8763)	9.8455 (3.8762)
	change	0.0003 (0.0001)	0	0	-0.0003(-0.0001)
Longitudinal	before	9.8450 (3.8760)	9.8463 (3.8765)	9.8455 (3.8762)	9.8448 (3.8759)
	after	9.8450 (3.8760)	9.8468 (3.8767)	9.8463 (3.8765)	9.8458 (3.8763)
	change	0	0.0005 (0.0002)	0.0008 (0.0003)	0.0010 (0.0004)



L-141 CYLINDER HEAD



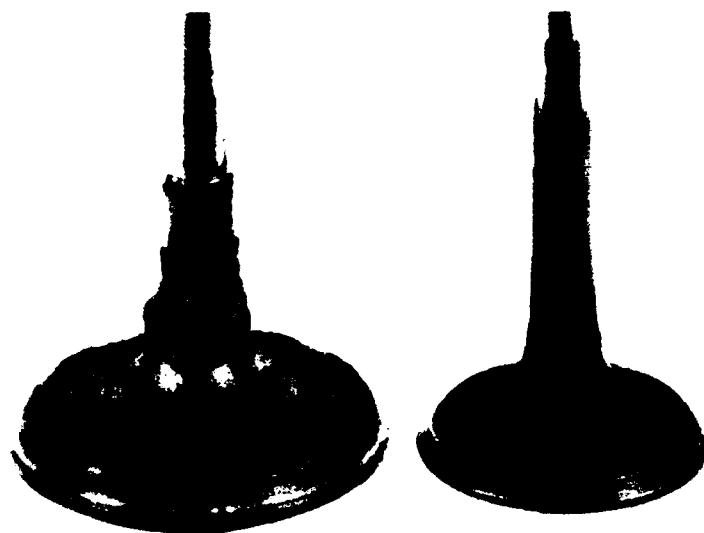
L-141 CYLINDER HEAD-CYLINDERS 2 & 3 (1.to r.)



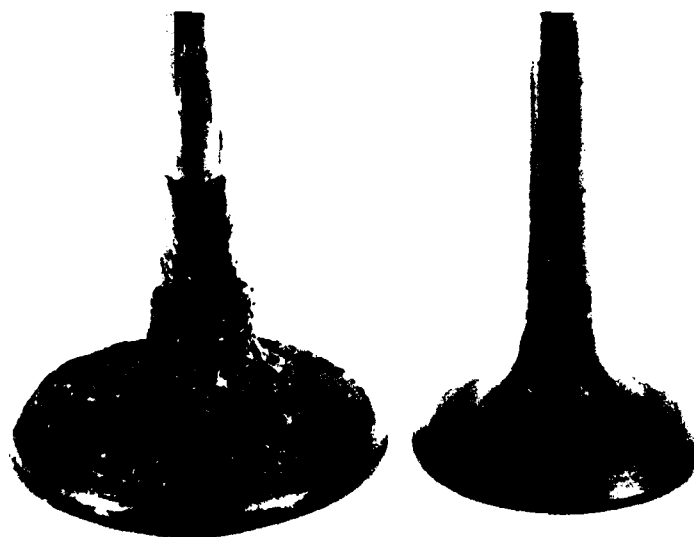
EXHAUST VALVE SEAT OF CYLINDER NO. 2
SHOWING VALVE RECESSION



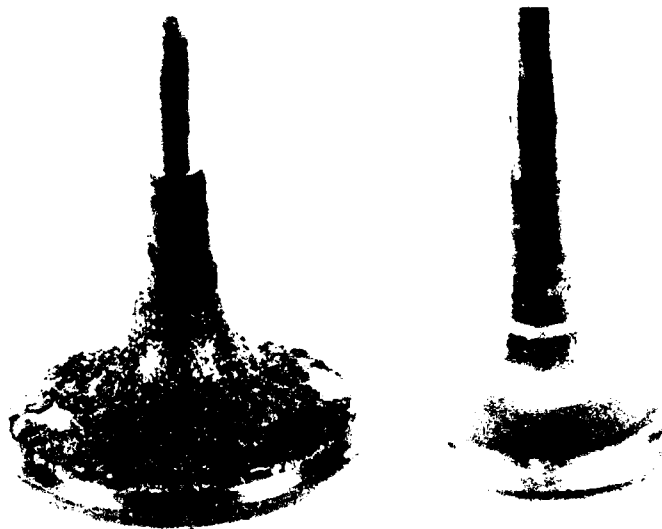
EXHAUST VALVE SEAT OF CYLINDER NO. 3
SHOWING VALVE RECESSION



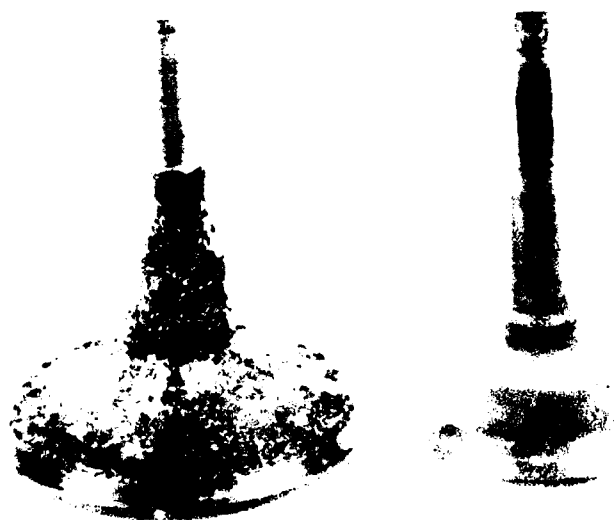
INTAKE AND EXHAUST VALVES - CYLINDER NO. 1



INTAKE AND EXHAUST VALVES - CYLINDER NO. 2



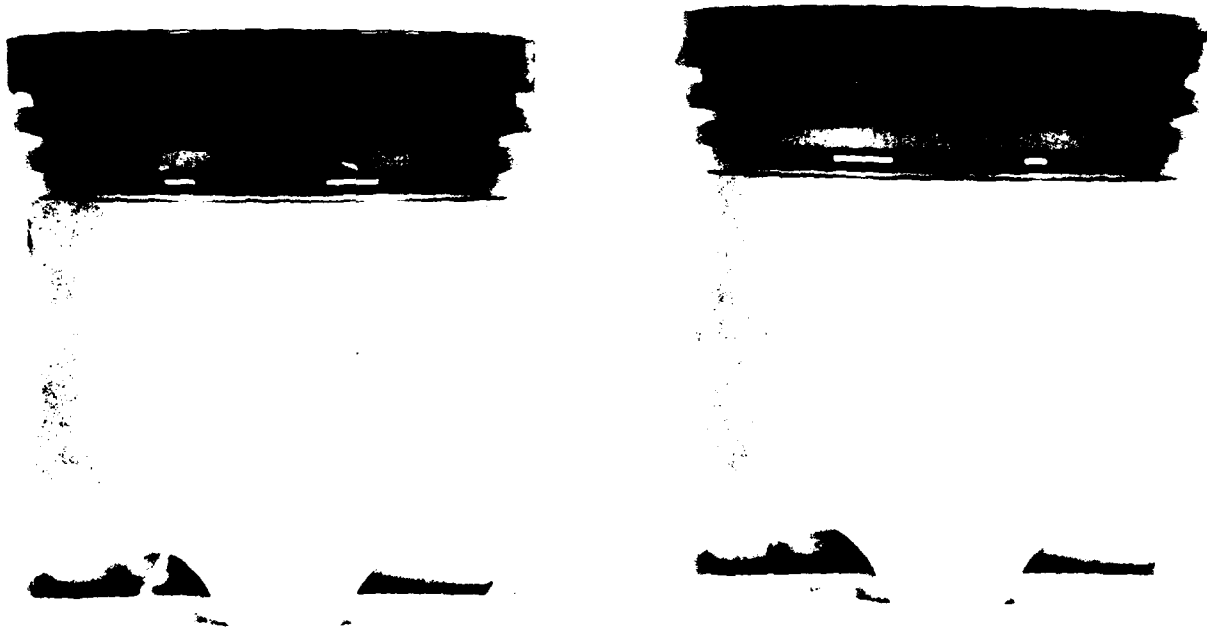
INTAKE AND EXHAUST VALVES - CYLINDER NO. 3



INTAKE AND EXHAUST VALVES - CYLINDER NO. 4



L-141 ENGINE OIL PAN



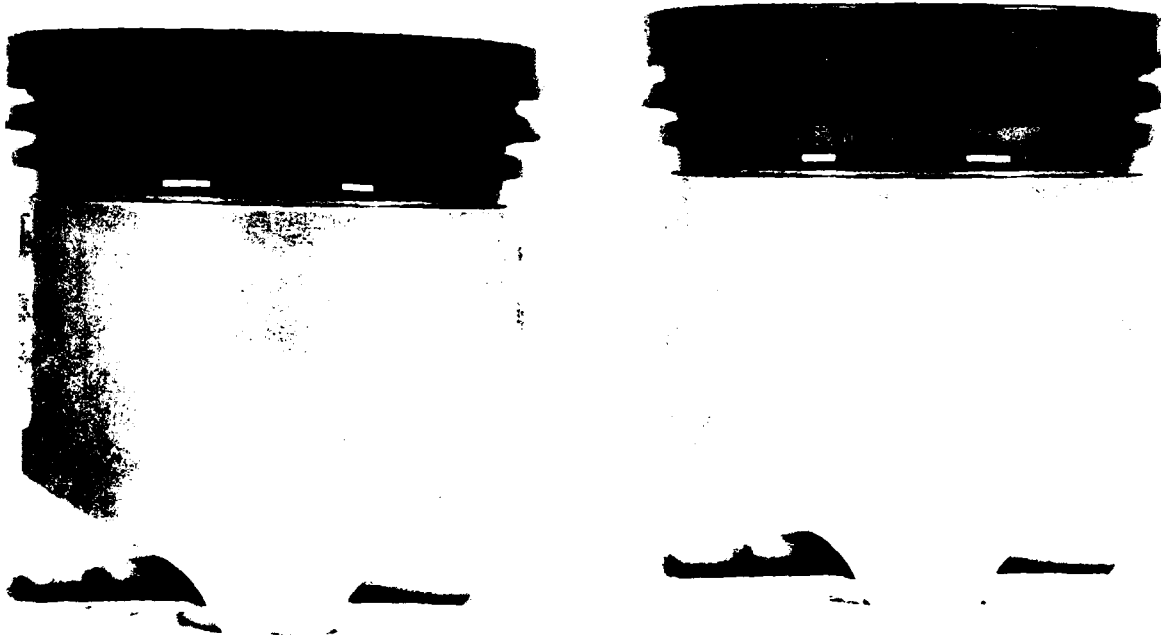
NO. 1 PISTON - THRUST & ANTI-THRUST



NO. 2 PISTON - THRUST & ANTI-THRUST



NO. 3 PISTON - THRUST & ANTI-THRUST



NO. 4 PISTON - THRUST & ANTI-THRUST

RING STICKING

Test No. 1

Engine Model Jeep L-141 Serial No. 5014646 Date 5-11-81

Fuel AL-10643-G Lubricant AL-9992-L Observer Lyons

Ring No.	Piston Number					
	1	2	3	4	2R	3R
1	F	F	F	F		
2	F	F	F	F		
3	F	F	F	F		
4	----	----	----	----		

Indicate by letter - Free or Sluggish, or by number and letter - percent Pinched
(cold stuck) or percent Hot stuck (Pages 6 and 7 of Manual).

RING DEPOSITS

Engine Model Jeep L-141 Serial No. 5014646 Date 5-11-81
 Fuel AL-10643-G Lubricant AL-9992-L Observer Lyons
 Test No. 1

Cylinder Number		1		2		3		4		2R		3R	
		CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN	CARB	LACQ	CARB	LACQ
Piston Ring	Top	1	0	60-2	0	10-2	0	100-2	0	85-5			
		2	0	90-8	0	90-8	0	50-7	0	90-8			
		3											
		4											
ID		1	100% A	0	100% A	0	100% A	0	100% A	0			
		2	100% A	0	0	100-9	0	100-9	0	100-9			
		3											
		4											
Bottom		1	0	60-2	0	60-2	0	60-2	0	100-5			
		2	0	70-8	0	80-8	0	40-7	0	80-8			
		3		30-5	0	10-6	0	60-3	0				
		4											

See pages 4, 36 and 37 of Manual. Areas previously rated for carbon, rate 0 for lacquer.

RING FACE CONDITION

Engine Model Jeep L-141 Test No. 1 Date 5-11-81
 Serial No. 5014646
 Fuel AL-10643-G Lubricant AL-9992-L Observer Lyons

	Cylinder Number					
	1	2	3	4	2R	3R
First Ring	N	N	LT. Vertical Lines on Face. (Blowby?) 2 % ring face burn. N	N		
Second Ring	N	N	N	N		
Third Ring	N	N	N	N		
Fourth Ring	----	----	----	----		
Oil Ring Slots -- % Open	100	100	100	100		

PISTON SURFACE DEPOSITS

Test No. 1

Engine Model Jeep L-141 Serial No. 5014646 Date 5-11-81

Fuel AL-10643-G Lubricant AL-9992-L Observer Lyons

		Piston Number						
		1	2	3	4	2R	3R	
Top*		1.5	2.0	1.5	1.5			
Combustion Chamber*		6.5	6.4	6.4	6.5			
Under Head*		6.0	5.8	6.0	6.0			
Skirts*	Thrust	0.5	0.5	0.5	0.5			
	Anti-Thrust	0.5	0.5	0.5	0.5			
Relief Areas*		0.5	0.5	0.5	0.5			
Lands	1	6.5	6.0	6.0	6.0			
	2	6.0	5.0	6.0	5.8			
	3	3.0	3.0	3.0	3.0			
	4	-----	-----	-----	-----			

Lacquer - Pages 4, 36, 37 of Manual.
 *Carbon and Ash: Use Volume Factor (Pages 5 and 40 through 47)
 Indicate H, M, or S (Page 5)

PISTON RING GROOVE DEPOSITS

Engine Model Jeep L-141 Serial No. 5014646 Date 5-11-81
 Test No. 1
 Fuel AL-10643-G Lubricant AL-9992-L Observer Lyons

		Cylinder Number													
		1		2		3		4		2R		3R			
		CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN	CARB	VARN		
Top of Groove*	1	0	25	0	30	0	10	0	20						
	2	0	0	0	50	0	0	0	50						
	3	0	100	0	100	0	100	0	100						
	4	---	---	---	---	---	---	---	---						
Back of Groove†	1	25	0	15	10	20	0	25	0						
	2	10	0	10	25	5	0	5	0						
	3	0	100	0	100	0	100	-	100						
	4	---	---	---	---	---	---	---	---						
Bottom of Groove*	1	0	0	0	0	0	0	0	0						
	2	0	100	0	100	0	0	100	0						
	3	0	0	0	0	0	0	0	0						
	4	---	---	---	---	---	---	---	---						
Drain Holes--% Blocked		0	---	---	---	---	---	---	---						

Lacquer: Pages 4, 36, and 37 *Carbon and Ash: Use Volume Factor (Pages 5 and 40 through 47)

Indicate H, M, or S (Page 5)

†Carbon and Ash: Indicate Percent Filled and H, M, or S (Page 5)

PISTON GROOVE INSIDE DIAMETER-% RING SUPPORTING CARBON

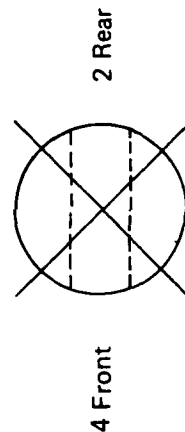
Test No. 1

Engine Model Jeep L-141 Serial No. 5014646 Date 5-11-81

Fuel AL-10643-G Lubricant AL-9992-L Observer Lyons

Piston Ring	Quadrant	Piston Number						
		1	2	3	4	2R	3R	
1	1	0	0	0	0			
	2	5	0	0	0			
	3	0	0	0	0			
	4	0	0	0	0			
2	1	0	0	0	0			
	2	0	0	0	0			
	3	0	0	0	0			
	4	0	0	0	0			

1 Thrust Side



4 Front

2 Rear

3 Anti-Thrust Side

PISTON SURFACE CONDITION

Engine Model Jeep L-141 Test No. 1 Date 5-11-81
 Fuel AL-10643-G Serial No. 5014646 Observer Lyons
 Lubricant AL-9992-L

	Piston Number					
	1	2	3	4	2R	3R
Top Land	N	N	N	N		
Skirt	N	N	N	N		
Piston Pin	N	N	N	N		

Pages 1 through 2 and 59 through 65 of Manual.

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

PISTON NO. 1

TEST PROCEDURE 150
 TEST HOURS 150
 TEST LABORATORY
 LUBRICANT AL-9992-L

RATER LYONS DATE 5-11-81
 LABORATORY TEST NUMBER 1
 STAND NO. 2 ENGINE NO. 5014646
 FUEL AL-10643-G

NO. 1 GROOVE, VOLUME %
 PISTON WTD* RATING 112.50

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES				LANDS				UNDER-CROWN	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4		
		AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT	AREA-% DEMERIT
CARBON	HC 1.00	5	5.00			10	10.00				
	MHC 0.75										
	MC 0.50	20	10.00			20	10.00				
	LC 0.25	55	13.75			30	7.50	50	12.50		
	VLC 0.15	10	1.50	85	12.75	15	2.25	25	3.75		
CARBON RATING		30.25	12.75			29.75	16.25				
LACQUER	BL 0.100		15	1.50		10	1.00				
	DB/L 0.075	10	0.75				0.375	25	1.875		100
	AL 0.050			100	5.00	10	0.50			100	5.00
	LAL 0.025										
	VLAL 0.010										
LACQUER RATING		0.75	1.50	5.00		1.875	1.875	5.00			7.50
CLEAN	0										
ZONAL RATING											
LOCATION FACTOR											
WEIGHTED RATING		31.00	14.25	5.00		31.625	18.125	5.00			7.50

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE _____
 TEST HOURS 150
 TEST LABORATORY _____
 LUBRICANT AL-9992-L

RATER Lyons DATE 5-11-81
 LABORATORY TEST NUMBER 1
 STAND NO. 2 ENGINE NO. 5014646
 FUEL AL-10643-G

PISTON NO. 2

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES				LANDS				NO. 1 GROOVE, VOLUME %	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	PISTON WTD* RATING	95.75
CARBON	HC 1.00					15	15.00				
	MHC 0.75										
	MC 0.50					35	17.50				
	LC 0.25	50	12.50			20	5.00				
	VLC 0.15	25	3.75	35	5.25	10	1.50	60	9.00		
LACQUER	CARBON RATING	16.25	5.25			39.00	9.00				
	BL 0.100	10	1.00	5	0.50		5	0.50			
	DBrL 0.075	15	1.125	60	4.50	10	0.75	35	2.625	100	7.50
	AL 0.050			100	5.00						
	LAL 0.025					10	0.25	100	2.50		
LACQUER RATING	VIAL 0.010										
	RL 0.001										
	CLEAN 0	2.125	10.25	5.00		1.00	3.125	2.50		7.50	
ZONAL RATING											
LOCATION FACTOR											
WEIGHTED RATING		18.375	10.25	5.00		40.00	12.125	2.50		7.50	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

RATER LYOTS DATE 5-11-81 PISTON NO. 3

TEST PROCEDURE 150

TEST HOURS 1

TEST LABORATORY 5014646

LUBRICANT AL-9992-L

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES										LANDS				UNDER-CROWN	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 1 GROOVE, VOLUME %	PISTON WTD* RATING
CARBON	HC	1.00								15	15.00						
	M-C	0.75															
	MC	0.50	5	2.50						55	13.75						
	LC	0.25	80	20.00						15	2.25	75	11.25				
	VLC	0.15	15	2.25	100	15.00				31.00	11.25						
LACQUER	CARBON RATING		24.75														
	BL	0.100															
	DBrL	0.075									25	1.875				100	7.50
	AL	0.050				100	5.00			15	0.375			100	2.50		
	LAL	0.025															
ZONAL RATING	VLAL	0.010															
	RL	0.001															
	LACQUER RATING									0.375	1.875	2.50				7.50	
	CLEAN	0															
	ZONAL RATING																
LOCATION FACTOR																	
WEIGHTED RATING			24.75							31.375	13.125	2.50				7.50	

*WEIGHTED TOTAL DEPOSITS

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE _____ DATE 5-11-81 _____
 TEST HOURS 150 _____
 TEST LABORATORY _____
 LABORATORY TEST NUMBER 1 _____
 STAND NO. 2 ENGINE NO. 5014546 _____
 FUEL AL-10643-G _____
 RATER LYONS _____
 PISTON NO. 4 _____
 NO. 1 GROOVE, VOLUME % _____
 PISTON WTD* RATING 135.375 _____

DEPOSIT TYPE	DEPOSIT FACTOR	GROOVES				LANDS				UNDER CROWN	
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2	NO. 3	NO. 4	NO. 1	NO. 2
CARBON	HC 1.00	10	10.00			5	5.00				
	MHC 0.75										
	MC 0.50										
	LC 0.25	90	22.50			85	21.25				
	VLC 0.15										
LACQUER	CARBON RATING	32.50	15.00			26.25	12.75				
	BL 0.100										
	DB/L 0.075			100	7.50		15	1.125		100	7.50
	AL 0.050										
	LAL 0.025					10	0.250			100	2.50
OTHER	V/LAL 0.010										
	RL 0.001										
	LACQUER RATING			7.50		0.250	1.125	2.50			7.50
	CLEAN 0										
	ZONAL RATING										
LOCATION FACTOR											
WEIGHTED RATING		32.50	15.00	7.50		26.50	13.875	2.50			7.50

*WEIGHTED TOTAL DEPOSITS

APPENDIX G

150-HOUR ENDURANCE TEST BASELINE RESULTS

APPENDIX G. TEST 1

Standard Piston Rings 150 hours Unleaded Gasoline Summary of Operating Conditions

<u>2800 rpm mode</u>	<u>Avg</u>	<u>Min</u>	<u>Max</u>
Torque, N-m (lb-ft)	127 (94)	126 (93)	130 (96)
Power, OBS, kW (bhp)	37.5 (50.3)	36.9 (49.5)	38.2 (51.3)
Specific Fuel Cons., kg/kW-hr (lb/bhp-hr)	0.331 (0.544)	0.259 (0.425)	0.351 (0.577)
Blowby @ 49°C (120°F), m ³ /h (cu ft/hr)	1.35 (47.8)	.932 (32.9)	1.57 (55.4)
Sump Temperature, °C (°F)	121 (250)	114 (238)	124 (256)
Manifold Vacuum, kPa (In. Hg)	10.5 (3.1)	9.1 (2.7)	11.1 (3.3)
<u>2200 rpm mode</u>	<u>Avg</u>	<u>Min</u>	<u>Max</u>
Torque, N-m (lb-ft)	129 (95)	114 (84)	133 (98)
Power, OBS, kW (bhp)	26.9 (36.1)	23.8 (32.0)	27.8 (37.3)
Specific Fuel Cons., kg/kW-hr (lb/bhp-hr)	0.352 (0.579)	0.274 (0.450)	0.369 (0.606)
Blowby @ 49°C (120°F), m ³ /h (cu ft/hr)	1.00 (35.3)	.770 (27.2)	1.25 (44.3)
Sump Temperature, °C (°F)	102 (216)	88 (191)	107 (225)
Manifold Vacuum, kPa (In. Hg)	10.1 (3.0)	9.5 (2.8)	11.8 (3.5)
<u>600 rpm mode</u>	<u>Avg</u>	<u>Min</u>	<u>Max</u>
Torque, N-m (lb-ft)	0	0	0
Power, OBS, kW (bhp)	0.0	0.0	0.0
Blowby @ 49°C (120°F), m ³ /h (cu ft/hr)	0.249 (8.8)	0.198 (7.0)	0.331 (11.7)
Sump Temperature, °C (°F)	62 (244)	51 (124)	69 (156)
Manifold Vacuum, kPa (In. Hg)	60.4 (17.9)	51.0 (15.1)	68.2 (20.2)

PRECEDING PAGE BLANK-NOT FILMED

APPENDIX G. TEST 1

Standard Piston Rings 150 hours

Used Oil Analysis

Test Hour	Viscosity, cSt *		Total Acid No.	Total Base No.	Fuel Dilu.,%	Water Dilu.,%
	40°C	100°C				
New	108	12.25	2.97	5.08	-	-
15	94	11.20	2.90	4.69	1.4	0.05
30	98	11.50	3.27	4.97	0.4	
45	102	11.75	3.27	4.69	0.6	
60	105	11.95	3.43	4.81	0.4	
75	106	12.00	2.85	4.97	nil	0.05
90	110	12.30	3.38	4.97		
105	109	12.50	3.27	4.13		
120	115	12.90	3.12	4.13		
135	120	13.05	3.38	4.69		
150	123	13.30	3.96	4.24	0.8	0.03

* Viscosity corrected to 40°C and 100°C from 38°C and 99°C using a viscosity versus temperature semi-log plot.

APPENDIX G. TEST 1

Standard Piston Rings 150 hours Oil Consumption

Test Hours	Oil Consumed, kg (lb)	Sample Removed, kg (lb)	Oil Added, kg (lb)
7.5	0	0	0
15	0.05 (0.1)	0.45 (0.10)	0.50 (0.11)
22.5	0	0	0
30	0	0.036 (0.08)	0.036 (0.08)
37.50	0.009 (0.02)	0	0.009 (0.02)
45	0	0.032 (0.07)	0.032 (0.07)
52.5	0	0	0
60	0.027 (0.06)0	0.041 (0.09)	0.068 (0.15)
67.5	0	0	0
75	0.35 (0.84)	0.036 (0.08)	0.36 (0.08)
82.5	0.132 (0.29)	0	0.132 (0.29)
90	0	0.041 (0.09)	0.41 (0.09)
97.5	0	0	0
105	0	0.036 (0.08)	0.036 (0.08)
112.5	0	0	0
120	0	0.055 (0.12)	0.55 (0.12)
127.5	0.027 (0.06)	0	0.027 (0.06)
135	0	0.045 (0.10)	0.045 (0.10)
142.5	0	0	0
150	0	0	0

Initial fill - 3.91 kg (8.60 lb)
Final drain - 3.10 kg (6.82 lb)
Change in filter wt. - 0.27 kg (0.60 lb)
Total oil consumed 0.74 kg (1.62 lb)

APPENDIX G. PISTON RING MEASUREMENTS

Test No. 1
 Engine Model: L-141
 Fuel: AL-5473

Serial No.: 5029085
 Lubricant: REO-203

Ring Configuration: Standard
 Dates: 12/4/74 - 1/2/75
 Observer: Jungman

		End Gaps, cm (inches)			
		Piston Number			
		1	2	3	4
Piston Ring Top Ring	before	0.056 (0.022)	0.043 (0.017)	0.048 (0.019)	0.053 (0.021)
	after	0.056 (0.022)	0.048 (0.019)	0.053 (0.021)	0.003 (0.001)
	change	0	0.005 (0.002)	0.005 (0.002)	0.003 (0.001)
Second Ring	before	0.058 (0.023)	0.061 (0.024)	0.056 (0.022)	0.061 (0.024)
	after	0.061 (0.024)	0.061 (0.024)	0.058 (0.023)	0.061 (0.024)
	change	0.003 (0.001)	0	0.003 (0.001)	0
		Side Clearance, cm (inch x 10 ⁻³)			
		Piston Number			
		1	2	3	4
Piston Ring Top Ring	before	0.005 (0.002)	0.008 (0.003)	0.005 (0.002)	0.005 (0.002)
	after	0.008 (0.003)	0.008 (0.003)	0.005 (0.002)	0.005 (0.002)
	change	0.003 (0.001)	0	0	0
Second Ring	before	0.008 (0.003)	0.008 (0.003)	0.005 (0.002)	0.008 (0.003)
	after	0.008 (0.003)	0.005 (0.002)	0.005 (0.002)	0.008 (0.003)
	change	0	-0.003(-0.001)	0	0

APPENDIX G. TEST 1

PISTON AND CYLINDER BORE MEASUREMENTS

Measurement Location		Cylinder Bore, cm (inches)			
		Piston Number			
		1	2	3	4
Transverse	before	9.8461 (3.8764)	1.1 cm from top 9.8486 (3.8774)	9.8453 (3.8761)	9.8450 (3.8760)
	after	9.8461 (3.8764)	9.8478 (3.8771)	9.8453 (3.8761)	9.8458 (3.8763)
	change	0	-0.0008(-0.0003)	0	0.0008 (0.0003)
Longitudinal	before	9.8463 (3.8765)	9.8476 (3.8770)	9.8453 (3.8761)	9.8455 (3.8762)
	after	9.8463 (3.8765)	9.8471 (3.8768)	9.8450 (3.8760)	9.8455 (3.8762)
	change	0	-0.0005(-0.0002)	-0.0003(-0.0001)	0
Transverse	before	9.8463 (3.8765)	5.87 cm from top 9.8476 (3.8770)	9.8453 (3.8761)	9.8453 (3.8761)
	after	9.8463 (3.8765)	9.8471 (3.8768)	9.8450 (3.8760)	9.8453 (3.8761)
	change	0	-0.0005(-0.0002)	-0.0003(-0.0001)	0
Longitudinal	before	9.8450 (3.8760)	9.8473 (3.8769)	9.8450 (3.8760)	9.8453 (3.8761)
	after	9.8445 (3.8758)	9.8468 (3.8767)	9.8448 (3.8759)	9.8453 (3.8761)
	change	-0.0005(-0.0002)	-0.0005(-0.0002)	-0.0003(-0.0001)	0

AD-A112 010 : SOUTHWEST RESEARCH INST SAN ANTONIO TX ARMY FUELS AN--ETC F/6 21/4
IMPACT OF GASOHOL ON THE L-141 AND LDT-465-1C ENGINES.(U)
DEC 81 W E LIKOS, D M YOST DAAK70-80-C-0001
UNCLASSIFIED AFLRL-148 NL

2 OF 2

AD A
120-3

END
DATE
FILMED

04-82
DTIC



2.5



W. H.
...

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

DEFENSE DOCUMENTATION CTR
CAMERON STATION 12
ALEXANDRIA VA 22314

DEPT OF DEFENSE
ATTN: DASD(MRAL)-LM(MR DYCKMAN) 1
WASHINGTON DC 20301

COMMANDER
DEFENSE FUEL SUPPLY CTR
ATTN: DFSC-T (MR. MARTIN) 1
CAMERON STA
ALEXANDRIA VA 22314

DOD
OFC OF SEC OF DEF
ATTN USD (R&E) 1
WASHINGTON, DC 20301

DEPARTMENT OF THE ARMY

HQ, DEPT OF ARMY
ATTN: DALO-TSE (COL ARNAUD) 1
DAMA-CSS-P (DR BRYANT) 1
DAMA-ARZ (DR CHURCH) 1
DAMA-SMZ 1
WASHINGTON DC 20310

CDR
U.S. ARMY MOBILITY EQUIPMENT
R&D COMMAND
Attn: DRDME-GL 10
FORT BELVOIR VA 22060

CDR
US ARMY MATERIEL DEVEL&READINESS
COMMAND
ATTN: DRCLDC (MR BENDER) 1
DRCDMR (MR GREINER) 1
DRCDMD-ST (DR HALEY) 1
DRCDE-SS 1
DRCIS-C (LTC CROW) 1
5001 EISENHOWER AVE
ALEXANDRIA VA 22333

CDR
US ARMY TANK-AUTOMOTIVE CMD
ATTN DRSTA-NW (TWVMO) 1
DRSTA-RG (MR HAMPARIAN) 1
DRSTA-NS (DR PETRICK) 1
DRSTA-G 1
DRSTA-M 1
DRSTA-GBP (MR MCCARTNEY) 1
WARREN MI 48090

DIRECTOR
US ARMY MATERIEL SYSTEMS
ANALYSIS AGENCY
ATTN DRXSY-CM 1
DRXSY-S 1
DRXSY-L 1
ABERDEEN PROVING GROUND MD 21005

CDR
US ARMY GENERAL MATERIAL &
PETROLEUM ACTIVITY
ATTN STSGP-F (MR SPRIGGS) 1
NEW CUMBERLAND ARMY DEPOT
NEW CUMBERLAND PA 17070

CDR
US ARMY RES & STDZN GROUP
(EUROPE)
ATTN DRXSN-UK-RA 1
BOX 65
FPO NEW YORK 09510

CDR
US ARMY FORCES COMMAND
ATTN AFLG-REG 1
AFLG-POP 1
FORT MCPHERSON GA 30330

CDR
US ARMY ABERDEEN PROVING GROUND
ATTN: STEAP-MT 1
ABERDEEN PROVING GROUND MD 21005

CDR
US ARMY YUMA PROVING GROUND
ATTN STEYP-MT (MR DOEBBLER) 1
YUMA AZ 85364

PROJ MGR, MOBILE ELECTRIC POWER
ATTN DRCPM-MEP-TM 1
7500 BACKLICK ROAD
SPRINGFIELD VA 22150

CDR
US ARMY EUROPE & SEVENTH ARMY
ATTN AEAGC-FMD 1
APO NY 09403

CDR
THEATER ARMY MATERIAL MGMT
CENTER (200TH)
DIRECTORATE FOR PETROL MGMT
ATTN AEAGD-MM-PT-Q (MR PINZOLA) 1
ZWEIBRUCKEN
APO NY 09052

CDR
 US ARMY RESEARCH OFC
 ATTN DRXRO-ZC 1
 DRXRO-EG (DR SINGLETON) 1
 P O BOX 12211
 RSCH TRIANGLE PARK NC 27709

CDR
 TOBYHANNA ARMY DEPOT
 ATTN SDSTO-TP-S 1
 TOBYHANNA PA 18466

DIR
 US ARMY MATERIALS & MECHANICS
 RSCH CTR
 ATTN DRXMR-EM 1
 WATERTOWN MA 02172

CDR
 US ARMY DEPOT SYSTEMS CMD
 ATTN DRSDS 1
 CHAMBERSBURG PA 17201

CDR
 US ARMY LEA
 ATTN DALO-LEP 1
 NEW CUMBERLAND ARMY DEPOT
 NEW CUMBERLAND PA 17070

CDR
 US ARMY FOREIGN SCIENCE & TECH
 CENTER
 ATTN DRXST-MT1 1
 FEDERAL BLDG
 CHARLOTTESVILLE VA 22901

CDR
 DARCOM MATERIEL READINESS
 SUPPORT ACTIVITY (MRSA)
 ATTN DRXMD-MD 1
 LEXINGTON KY 40511

HQ, US ARMY T&E COMMAND
 ATTN DRSTE-TO-O 1
 ABERDEEN PROVING GROUND, MD 21005

HQ, US ARMY TROOP SUPPORT &
 AVIATION MATERIAL READINESS
 COMMAND
 ATTN DRSTS-MEG (2) 1
 DRCPO-PDE (LTC FOSTER) 1
 4300 GOODFELLOW BLVD
 ST LOUIS MO 63120

DEPARTMENT OF THE ARMY
 CONSTRUCTION ENG RSCH LAB
 ATTN CERL-EM 1
 P O BOX 4005
 CHAMPAIGN IL 61820

HQ
 US ARMY TRAINING & DOCTRINE CMD
 ATTN ATDO-5 (COL MILLS) 1
 FORT MONROE VA 23651

CDR
 US ARMY NATICK RES & DEV CMD
 ATTN DRDNA-YEP (DR KAPLAN) 1
 NATICK MA 01760

CDR
 US ARMY TRANSPORTATION SCHOOL
 ATTN ATSP-CD-MS 1
 FORT EUSTIS VA 23604

CDR
 US ARMY QUARTERMASTER SCHOOL
 ATTN ATSM-CD (COL VOLPE) 1
 ATSM-TNG-PT 1
 FORT LEE VA 23801

CDR
 US ARMY LOGISTICS CTR
 ATTN ATCL-MS (MR A MARSHALL) 1
 FORT LEE VA 23801

DEPARTMENT OF THE NAVY

CDR
 DAVID TAYLOR NAVAL SHIP R&D CTR
 CODE 2830 (MR G BOSMAJIAN) 1
 CODE 2831 1
 ANNAPOLIS MD 21402

JOINT OIL ANALYSIS PROGRAM -
 TECHNICAL SUPPORT CTR 1
 BLDG 780
 NAVAL AIR STATION
 PENSACOLA FL 32508

DEPARTMENT OF THE NAVY
 HQ, US MARINE CORPS
 ATTN LPP (MAJ SANDBERG) 1
 WASHINGTON DC 20380

CDR
 NAVAL FACILITIES ENGR CTR
 ATTN CODE 1202B (MR R BURRIS) 1
 CODE 120B (MR BUSCHELMAN) 1
 200 STOVALL ST
 ALEXANDRIA VA 22322

CDR, NAVAL MATERIAL COMMAND
ATTN MAT-08E (MR ZIEM) 1
CP6, RM 606
WASHINGTON DC 20360

CDR
NAVY PETROLEUM OFC
ATTN CODE 40 1
CAMERON STATION
ALEXANDRIA VA 22314

CDR
MARINE CORPS LOGISTICS SUPPORT
BASE ATLANTIC
ATTN CODE P841 1
ALBANY GA 31704

DEPARTMENT OF THE AIR FORCE

HQ, USAF
ATTN LEYSF (MAJ LENZ) 1
WASHINGTON DC 20330

HQ AIR FORCE SYSTEMS CMD
ATTN AFSC/DLF (LTC RADLOF) 1
ANDREWS AFB MD 20334

CDR
USAF SAN ANTONIO AIR LOGISTICS
CTR
ATTN SAALC/MMPRR 1
KELLY AIR FORCE BASE, TX 78241

CDR
USAF WARNER ROBINS AIR LOGISTIC
CTR
ATTN WR-ALC/MMIRAB-1 (MR GRAHAM) 1
ROBINS AFB GA 31098

OTHER GOVERNMENT AGENCIES

US DEPARTMENT OF TRANSPORTATION
ATTN AIRCRAFT DESIGN CRITERIA
BRANCH 2
FEDERAL AVIATION ADMIN
2100 2ND ST SW
WASHINGTON DC 20590

US DEPARTMENT OF ENERGY
DIV OF TRANS ENERGY CONSERV 2
ALTERNATIVE FUELS UTILIZATION
BRANCH
20 MASSACHUSETTS AVENUE
WASHINGTON DC 20545

DIRECTOR
NATL MAINTENANCE TECH SUPPORT
CTR 2
US POSTAL SERVICE
NORMAN OK 73069

US DEPARTMENT OF ENERGY
BARTLESVILLE ENERGY RSCH CTR
DIV OF PROCESSING & THERMO RES 1
DIV OF UTILIZATION RES 1
BOX 1398
BARTLESVILLE OK 74003

SCI & TECH INFO FACILITY
ATTN NASA REP (SAK/DL) 1
P O BOX 8757
BALTIMORE/WASH INT AIRPORT MD 21240

LMED
-8